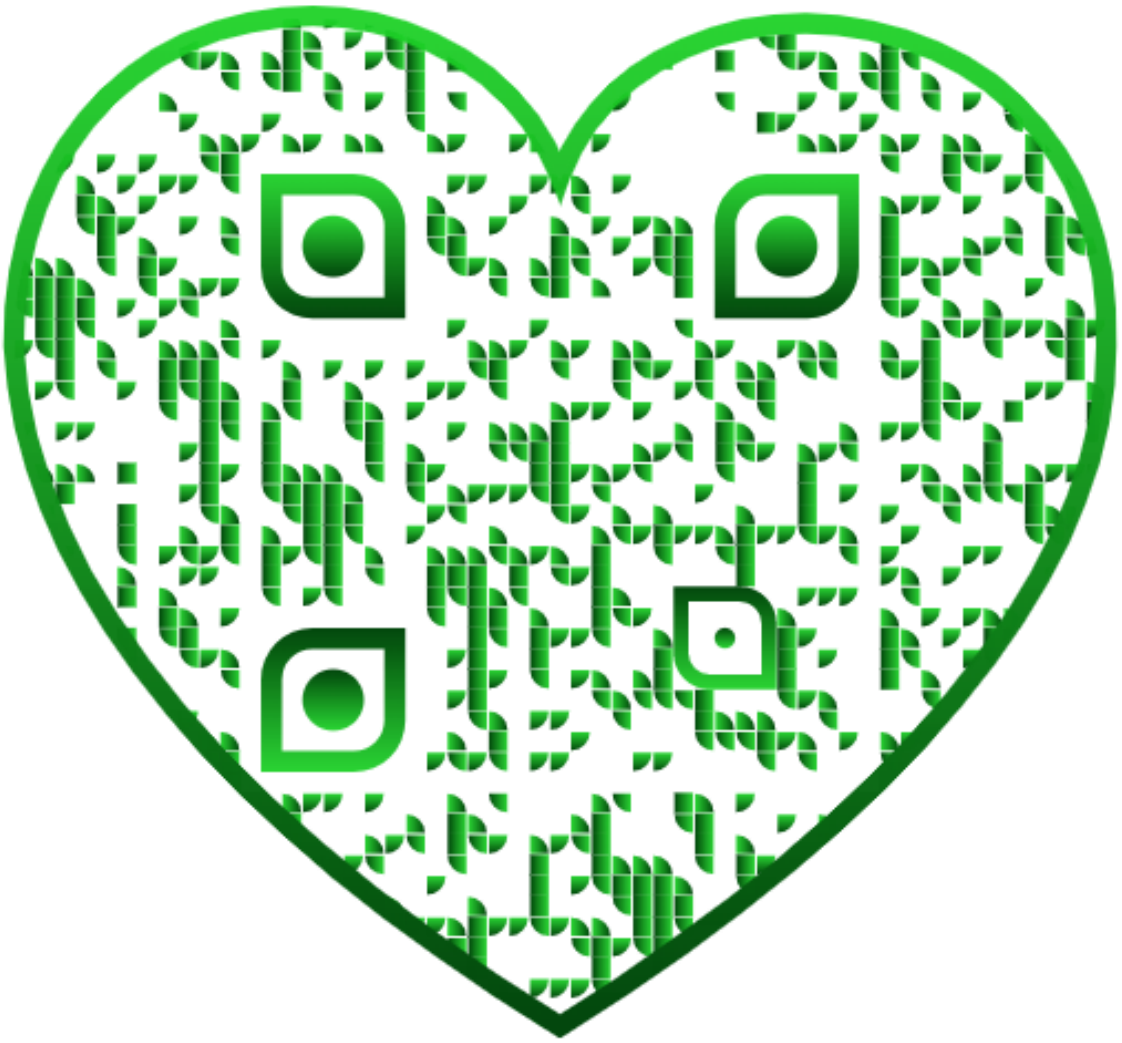
PERMA~ CULTURE TWO

Practical Design for Town and Country in Permanent Agriculture.

By Bill Mollison.

SHOUT
SHARE
IT



PERMA-CULTURE TWO

". . . If there is a single claim, that I could make, in order to distinguish Permaculture from other systems of agriculture, with the notable exception of keyline concepts, it is that Permaculture is primarily a *consciously designed* agricultural system . . . a system that combines landscape design with perennial plants and animals to make a safe and sustainable resource for town and country. A truly appropriate technology giving high yields for low energy inputs, and using only human skill and intellect to achieve a stable resource of great complexity and stability."

". . . Permaculture Two is about design, not gardening or livestock *per se* but as elements in a system intended to serve man, and the ends of good ecology . . . Good teachers have nothing to give but enthusiasm to learn; they cannot with the best will in the world, give their students knowledge. Thus it is 'how' to design, rather than designing your site which I am attempting here . . ."

". . . both individual and competitive enterprise, and 'free' energy have failed us. Society is in a mess; obesity in the west is balanced by famine in the third world. Petrol is running out yet freeways are still being built. Against such universal insanity the only response is to gather together a few friends and commence to build the alternative on a philosophy of individual responsibility for community survival."

Permaculture.... A Self-supporting Design for Tomorrow.

U.S.A. $10.95

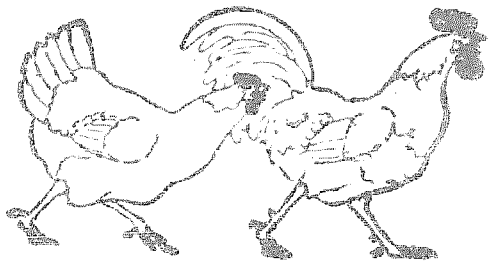
INTERNATIONAL TREE CROPS INSTITUTE
BOX 1272 • WINTERS, CA 95694

Australia $8.00 (Rec.) New Zealand $8.50

PERMA-CULTURE TWO

Practical Design for Town and Country in Permanent Agriculture.

By Bill Mollison.



TAGARI

PERMACULTURE II: Practical Design and Further Theory in Permanent Agriculture.

A Tagari Community Book
First Publication Australia, 1979
First Print 25,000

Copyright © Bill Mollison, 1979
National Library of Australia Card and I.S.B.N. 0 908228 00 7

The contents of this book, and the word "Permaculture" are copyright. Apart from any fair dealing for the purpose of private study, research, criticism or review as permitted under the Copyright Act, no part may be reproduced by any process without written permission from the author. Enquiries should be made to the publisher.

Cover design and illustrations: Janet Mollison, Andrew Jeeves
Photographs: Bill Mollison

Tagari Books are published by
TAGARI
P.O. Box 96, Stanley,
Tasmania, 7331,
Australia.
Ph: 004-581105.
(Mail-order and trade enquiries welcomed)

Made and printed in Australia by Hedges and Bell, Maryborough, Victoria.

" . . . that veteran of Virgil's I recall
Who made a kitchen garden by the Galaesus
On derelict land, and got the first of spring
From airs and buds, the first fruits in the fall
And lived at peace there, happy as a king.

. . . . . .

I see man's native
Stock is perennial, and our creative
Winged seed can strike a root in anything."

Cecil Day Lewis[10]

Conventions

References

As in Permaculture One, minor references are given in the text; major sources are listed in full, sometimes with a short annotation as to their usefulness, in Section 10 of this book, and Appendix D of Permaculture One (with some overlap in references).

Seasons and Directions

All months, seasons and directions are given for the southern hemisphere. For corresponding equivalents in the northern hemisphere it is simply necessary to reverse directions, and for planting times add 6 months. All units are used in the original form.

Abbreviations Used

P.I. = Permaculture One
P.II = Permaculture Two
P.C. = Permaculture
P.Q. = Permaculture Quarterly, the journal of the Permaculture Association.

Tagari

Tagari is a small group of about 30 (but growing) parents, single people and children devoted to the evolution of the meta-industrial village*, and to experiments in alternative systems of agriculture and industry. It is a non-profit association, where surplus goes to furthering these aims. The writer is a foundation member, with his wife and friends.

Please keep letters sparse and informative; we are very busy. If impelled to write, enclose self-addressed and stamped envelope; a few spare stamps also help. Workers are welcome in season, but please write first.

*See, for a model, William Thompson, *Darkness and Scattered Light,* Anchor Books, 1978.

Cover Story

Concept: Janet Mollison, Artwork: Andrew Jeeves.

Within the circle is a "rolling permaculture" system of linked sun trap/wind break plantings (see Figs. 4.5, 4.6), each containing an element which takes advantage of the extra heat and light: a dwelling (glasshouse—fronted with reflection pond in front) and annual garden; a milking shed; a polycultural pond; and a "simultaneous rotation" Fukuoka grain/legume/pulse plot.

Outside the circle are the elements of life: air, fire, water, earth and time.

Between these lies the landscape shaper of aboriginal mythology . . .

"We have a legend that explains the formation of the hills, the rivers and all the shapes of the land. Everytime it rains and I see a beautiful rainbow I am reminded of the legend of the Rainbow Serpent . . .

In the beginning the earth was flat, a vast grey plain. As the rainbow serpent wound his way across the land, the movement of his body heaped up the mountains and dug troughs for the rivers. With each thrust of his huge multi-coloured body a new land form was created.

At last, tired with the effort of shaping the earth, he crawled into a waterhole. The cool water washed over his vast body, cooling and soothing him . . . Each time the animals visited the waterhole, they were careful not to disturb the Rainbow Serpent, for although they could not see him they knew he was there. Then one day, after a huge rainstorm, they saw him. His huge coloured body was arching up from the waterhole, over the tree tops, up through the clouds, across the plain to another waterhole.

To this day the Aboriginals are careful not to disturb the Rainbow Serpent, as they see him, going across the sky from one waterhole to another."

From *Gulpilil's Stories of the Dreamtime,* compiled by Hugh Rule and Stuart Goodman, published by William Collins, Sydney, 1979.

Acknowledgments

P.II is rather a family affair, with Phil (my wife) typing, correcting and enduring; Janet (my daughter) fitting in some illustrations between formal studies and the members of Tagari assisting as needed. Andrew Jeeves in particular assisting with illustrations and proof reading.

A great many people have contributed ideas and solutions to this book. In particular, I would like to acknowledge the fruitful discussions I have had with Geoff Wallace, Ken and P. A. Yeomans, Deborah White and Victor Papanek; and the encouragement of people I admire, like Ken Kern, Earle Barnhardt (New Alchemists), Stephen Gaskin (The Farm, Tennessee), Robert de Hart (co-author of *Forest Farming*) and innumerable friends in the alternative lifestyle movement.

In Australia, Terry White continues to edit the Permaculture Quarterly despite financial constraints, and a great many self-sufficiency freaks (with and without blue rinses and bare feet) have implemented many of the designs that were still theory in P.I., and have spread acceptance of the system far and wide.

Contents

	conventions		iv
	acknowledgements		v
1			1
INTRODUCTION	1.1	The Underlying Philosophy.	1
	1.2	On Permanent Agriculture.	3
2			6
DESIGN IN	2.1	On Design.	7
LANDSCAPE	2.2	Design Criteria.	7
		1 Deciding Priorities	
	2.3	Zone and Sector Ground Planning.	10
		1 How to Place Elements in Zones	
		2 How to Place Elements in Sectors	
	2.4	Broadscale Landscape Analysis	16
		1 Taking Advantage of Slope	
	2.5	How Much Land?	22
	2.6	The Stacking of Plants.	23
		1 System Establishment	
	2.7	The Interaction of Plants and Animals	24
		1 Animals	
3			29
SOIL	3.1	Broadscale Soil Improvement	29
IMPROVEMENT	3.2	No-tillage Cropping	33
		1 Green Crops	
		2 Pulses and Legumes, Hedgerow, Oil Plants	
		3 Distribution of Yield	
	3.3	Sheet Mulch for Home Gardens	40
		1 Living Mulch	
		2 Stone Mulch	
		3 Keeping your Annuals Perennial	
4			46
BROADSCALE	4.1	Planning an Even Fodder Distribution	46
TECHNIQUES	4.2	Rolling Permaculture for Larger Properties	48
		1 On-farm and Urban Production of fuels from Plants	
	4.3	Orchards	52
		1 Pruning—Necessity or Habit?	
	4.4	Woodlots and Hedgerows	53
5			56
DESIGN FOR	5.1	Arid Lands	56
DIFFICULT		1 Local Strategies	
CLIMATES		2 Livestock	
		3 Aboriginal Skills	
		4 Permanent Grain Plots	

Poultry Forage Systems 5
Notes on Aboriginal Nutrition 6
Annotated List of Useful Arid Land Species 7
Acknowledgements and Apologia 8

85 Tropics 5.2
Humid Tropics 1
87 Sea Coasts 5.3
89 The Creation of Small Climates 5.4

90 **6**
90 The Reactive House 6.1 STRUCTURES
92 House Modifications 6.2
94 The Basic Sun-Wind Defences or Alliances 6.3
95 Some Novel Houses 6.4
Earth Houses 1
Plant Houses 2
102 Minor Designs and Techniques 6.5
Sound Walls 1
The Sod Roof 2
Fire Mandalas 3
Windows 4
Back to the Cave 5
Sewage and other Filthy Matters 6

7
107 Aquatic Polyculture 7.1 WATERWORKS
107 Waterworks Construction 7.2
Nomenclature of Ponds and Lakes 1
124 Pond Culture 7.3
129 Public Policy—the Sport Fishery 7.4
129 *Salicornia* Flats 7.5
130 Mariculture 7.6
Tidal Stone Traps 1
Seagrasses (*Zostera, Heterozostera* and *Posidonia*) 2

133 **8**
136 Establishment 8.1 FREE RANGE
136 Forage Storage 8.2 POULTRY
136 Regulation of Yield 8.3 DESIGN
138 Documentation 8.4
Species with Seeds and Pods in Summer 1
Trees and Shrubs yielding Nuts or Acorns for Storage (autumn-spring) 2
Berries and Fruits yielding Flesh or Seed (late summer-mid-winter) 3
Vines for Fences and Trellis 4
Roots 5
Greens and Seeds as Herb Layer 6
Species for Broadcast Sowing in Straw-Yards 7
Herbs, "Weeds" and "Throwover" Crop 8
Layout 9

9 ON PERMACULTURE AND COMMUNITY 142
Action for People 143

10 FURTHER RESOURCES 145
Design Consultancy 145
Standard Designs 145
Permaculture Quarterly and Association 147
The Permaculture Institute 147
Permaculture Species Index 147
Tagari 147

11 MAIN REFERENCES 148

Permaculture Two

TAGARI

INTRODUCTION 1

It must be stated at the outset that I regard permanent agriculture as a valid, safe, and sustainable, complete energy system. Permaculture, as defined here, claims to be designed agriculture, so that the species, composition, array and organization of plants and animals are the central factor. In that sense this is not a gardening book.

Permaculture One may thus be the first book on plants in which functional design (not cosmetic array) is the central theme; for we have many more energy benefits from design than we have from random placement of species, beyond the intrinsic value of plants or animals.

Permaculture Two attempts to make practical suggestions as to how these energy benefits are to be obtained, from domestic to broadacre environments. Plants are not only beneficial of themselves, but also modify local climate and many forms of pollution. Permaculture is a dispersed system, available to anybody who can garden. Centred on human settlement or community, it holds the welfare of man and the needs of the people it is intended to serve as the paramount concern. The intention of P.II then, is not to define a particular solution or to list designs for all climates and occasions, but to instance the ways in which people have evolved new approaches and solutions—most of them needing minimal energy, and all of them producing more calories than they consume.

Permaculture now has had many trials throughout Australia, in many climatic regions. Neither David Holmgren nor myself anticipated the strong response to P.I. and the subsequent demand for detailed planning and lectures, workshops and seminars, consultancy and on-site design.

Many people wrote to say they were practising, or thinking of, similar systems, and that we had expressed their almost-formulated ideas in P.I. which was a hurried re-make of our rather stuffy notes, and it is with more leisure and pleasure that this second book is planned and written. As it cannot cover all cases, or climates, local adaptations will need to be made by readers, but the idea of planning for low-energy systems should be clear.

I hope and believe that the systems presented here will be eclipsed by more carefully designed arrays as we gain experience and information by working with whole systems.

THE UNDERLYING PHILOSOPHY 1·1

> "In this world, things are complicated and are decided by many factors. We should look at problems from different aspects, not from just one."
>
> —Mao Tse Tung, 1945

Perhaps Fukuoka,[3] in his book *The One Straw Revolution,* has best stated the basic philosophy of permaculture. In brief, it is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labour; and of looking at plants and animals in all their functions, rather than treating any area as a single-product system. The difference is like that which exists between the Aboriginal and the ploughman: the latter is seen as one who would cut open his mother's breast to obtain milk, the former takes only what is given freely, and takes it with due reverence.

Had we studied the diverse yield of the American prairies, the African savannahs, and the Australian bush, we may have found (as we have found in later analysis) that they gave us more in their natural state than they do as ploughed and fenced systems. For Africa it is estimated that production of meat protein alone fell to 1/60th of its natural level when we cleared, fenced, ploughed, sowed pasture and introduced exotic cattle. Here, then, we see senseless energy or "hard work" as a destructive effect in nature. Often enough, in Australia, we can find one grazier barely existing on lands that supported two to three hundred Aborigines.

But for people with little free energy, it is inspirational to read of what Fukuoka[3] and Bouffier[28] achieved, on foot over large acreages, and with large yields. In Central Honduras, Andersen[18] describes the gardens about the little houses:

1.1 Close to the house and frequently more or less surrounding it is a compact garden-orchard several hundred square feet in extent. No two of these are exactly alike. There are neat plantations more or less grouped together. There are various fruit trees (nance, citrus, melias, a mango here and there, a thicket of coffee bushes in the shade of the larger trees) . . . There are tapioca plants of one or two varieties, grown more or less in rows at the edge of the trees. Frequently there are patches of taro; these are the framework of the garden-orchards. Here and there in rows or patches are corn and beans. Climbing and scrambling over all are vines of various squashes and their relatives; the chayote (choko) grown for the squashes, as well as its big starchy root. The luffa gourd, its skeleton used for dishrags and sponges. The cucurbits clamber over the eaves of the house and run along the ridgepole, climb high in the trees, or festoon the fence. Setting off the whole garden are flowers and various useful weeds (dahlias, gladioli, climbing roses, asparagus fern, cannas). Grain amaranth is a "sort of encouraged weed that sows itself".

Around the "dooryard gardens" described above, he notes the fields (in Mexico) "dotted here and there with volunteer guavas and guamuchiele trees, whose fruit was carefully gathered. Were they orchards or pastures "What words are there in English to describe their groupings?"

Andersen is contrasting the strict, ordered, linear, segmented thinking of Europeans with the productive, more natural polyculture of the dry tropics. The order he describes is a semi-natural order of plants, in their right relationship to each other, but not separated into various artificial groupings. More than that, the house and fence form essential trellis for the garden, so that it is no longer clear where orchard, field, house and garden have their boundaries, where annuals, and perennials belong, or indeed where cultivation gives way to naturally-evolved systems.

Monoculture man (a pompous figure I often imagine to exist, sometimes fat and white like a consumer, sometimes stern and straight like a row-crop farmer) cannot abide this complexity in his garden or his life. His is the world of order and simplicity.

Permaculture Two then, is about design, not gardening or livestock *per se* but as elements in a system intended to serve man, and the ends of good ecology. But, as Fukuoka[3] notes:

"Changes, to be of any consequence, must come first at the basic philosophical level."

and the changes I seek are very much a matter of philosophy, a search for the right question, rather than the answer to any question. Of the two questions—What can I demand this land to do? or—What does this land have to give me?—the first leads to a forcible rape of land by machinery, and the second to a sustained ecology supported by the intelligent control of man. It is war or peace, and the latter takes more thought than the former.

Standing at the centre, or sitting at your back doorstep, all you need to live a good life lies about you. Sun, wind, people, buildings, stones, sea, birds and plants surround you. Co-operation with all these things makes harmony, opposition to them brings dissonance and chaos. Fukuoka[3] speaks of *mahayana,* of farming as sacred work in the service of nature, of how people of all religions are attracted to his farm, and his philosophy of natural living and growing, of making no difference between oneself and the world, (for there is no difference, but we can know this only by not wanting to know *about* it). All we can do is assist in the complexity of life, we cannot create life. By "trying too hard" though, we can easily destroy life.

I have spoken, on a more mundane level, of using aikido on the landscape, of rolling with the blows, turning adversity into strength, and using everything positively. The other approach is to karate the landscape, to try to make it yield by exerting your strength, and striking many hard blows. But if we attack nature we attack (and destroy) ourselves. We can only hope to understand, to use what is there. Let us look at Fukuoka's four principles of growing:

1 *No Cultivation*—do not turn the soil over, and so cause injuries which attempt to heal themselves.
2 *No chemical fertilizer or prepared compost*—let the plants and animals that make the soil go to work on the soil.
3 *No weeding by tillage or herbicide*—use the weeds; control them by natural means, or occasional cutting.
4 *No dependence on chemicals*—Insects and disease, weeds and pests, have their own controls—let these operate, and assist them.

This is indeed a low-energy system of agricultural strategy.

There is more than one way to achieve permanence and stability in land or society. The peasant approach is well described by King[5] for old China. Here man hauled nutrients from canals, cesspits, pathways and forests to an annual grain culture. We could describe this as 'feudal permanence' for its methods, period and politics. Man bound to landscape by unremitting toil, and in service to a landlord. This leads eventually to famine and revolution.

A second approach is the permanent pasture of prairie, pampas, and modern western farms, where large holdings and few people create vast grazing leases, usually for a single species of animal. This is best described as 'baronial permanence' with near-regal properties of immense extent, working at the lowest possible level of land use; for pasture is the least productive use of land we can devise. Such systems, once mechanized, destroy whole landscapes and soil complexes.

Forests, not seen by industrial man as anything but wood, are another permanent agriculture. But they need generations of care and knowledge, and hence a tribal or communal reverence only found in stable communities. This then, is the communal permanence many of us seek. To be able to plant a pecan or citrus when we are old, and to know it will not be cut down by our children's children.

The further we depart from communal permanence, the greater the risk of tyranny, feudalism, and revolution and the more work for less yield. Any error or disturbance can bring disaster, as can a drought year in a desert grain crop or a distant political decision on tariffs.

The real risk is that the needs of those "on the ground"—the inhabitants—are overthrown by the needs (or greeds) of commerce and centralized power; that the forest is cut for warships or newspaper and we are reduced to serfs in a barren landscape. This has been the fate of peasant Europe, Ireland, and much of the third world.

I can roughly diagram the way forward to less energy use, but greed and senseless use may as easily reverse the process. The diagram (Fig. 1.1) is a very simple but sufficient illustration of the case I am making. Selected forests not only yield more than annual crops, but provide a diverse nutrient and fuel resource for such crops.

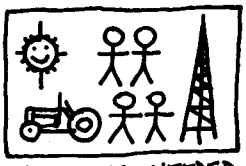
The characteristic that typifies all permanent agricultures is that the needs of the system for energy, are provided by that system. Modern crop agriculture is totally dependant on external energies—hence the oil problem.

Without permanent agriculture there is no possibility of a stable social order. When I coined the word permaculture I had both social and environmental factors in mind. It may be possible that overpopulation itself is a response to increased energy needs in annual (peasant) crops, as it was never a problem in forested areas, nor is it where energy excess is locally available, as in industrialized or technologized villages, or in tribal areas.

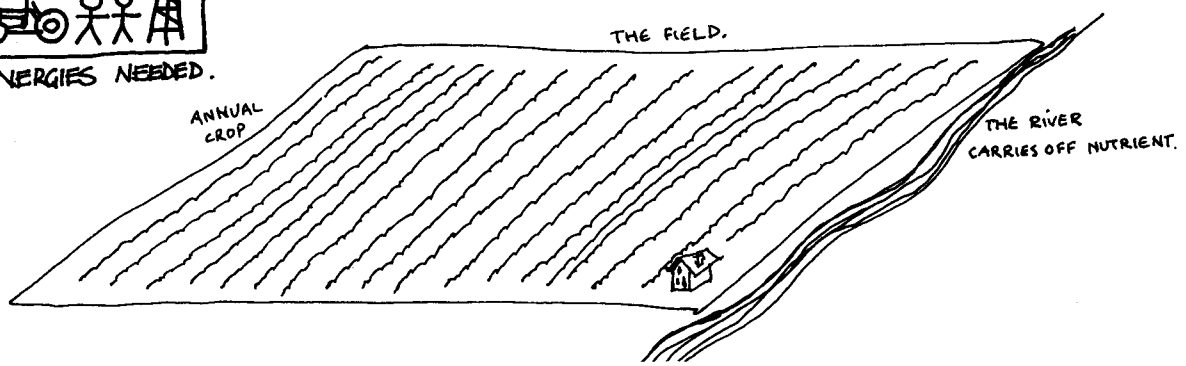
Thus, the departure from productive permanent systems, where the land is held in common, to annual, commercial agricultures where land is regarded as a commodity involves a departure from a low to a high-energy society, the use of land in an exploitive way, and a demand for external energy sources, mainly provided by the third world. People think I am slightly crazy when I tell them to go home and garden, or *not* to involve themselves in broadscale mechanized agriculture; but a little thought and reading will convince them that this is, in fact, the solution to many world problems.

What is now possible is a totally new synthesis of plant and animal systems, using a post-industrial and even computerised approach to system design, applying the principles of whole system energy flows as devised by Odum[19], and the principles of good ecologies as enunciated by Watt[14] and others. It is, in the vernacular, a whole new ball game to devise permaculture systems for local, regional, and personal needs.

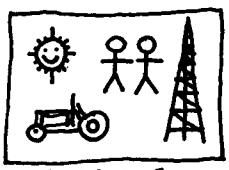
The Aborigines of Tasmania left to their descendants a legend of "true signs"—something that happens to you *here* means something else is happening *there*. Something that happens *now* means something else will happen *later*. Ghosts pluck at the muscles of the shoulder as someone



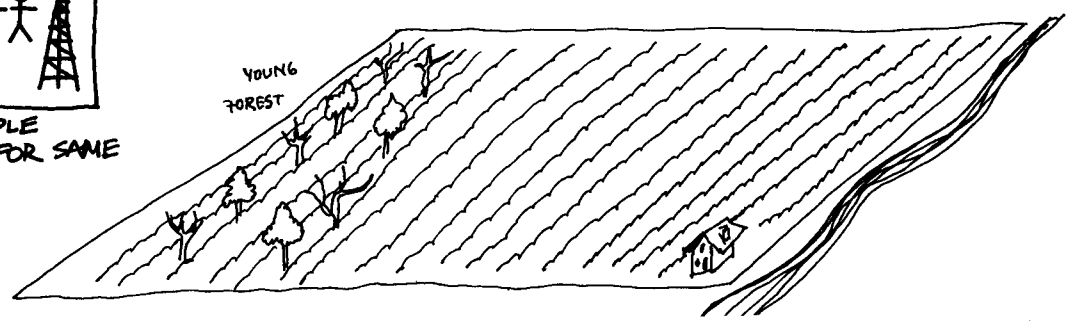
ENERGIES NEEDED.



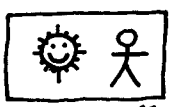
1 ANNUAL AGRICULTURE. HIGH CONSUMPTION OF ENERGY.



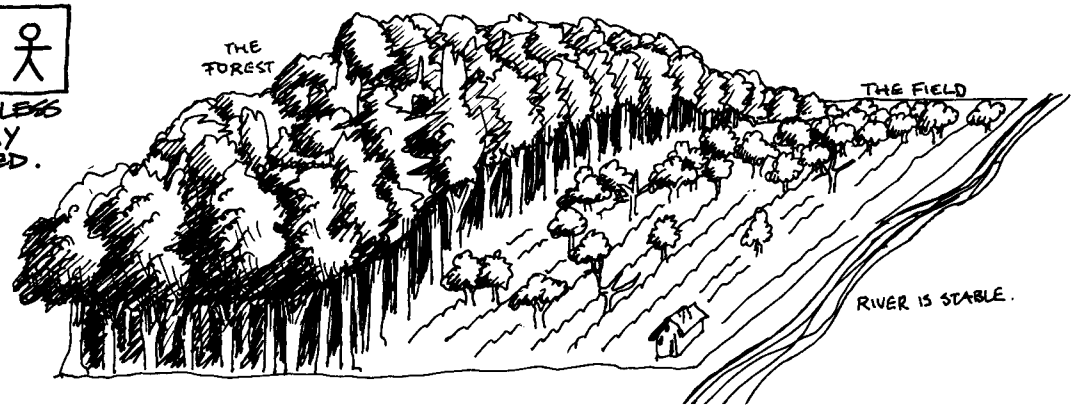
LESS PEOPLE NEEDED FOR SAME YIELD.



2 CONVERSION TO PART YIELDING FOREST — ENERGY NEEDS AND NUTRIENT LOSS REDUCED.



MUCH LESS ENERGY NEEDED.



3 CONVERSION COMPLETED. YIELDING FOREST SUPPLIES FUEL AND NUTRIENTS FOR A SMALL ANNUAL GARDEN. THERE IS A HIGHER TOTAL YIELD.

FIG. 1·1: CONVERSION FROM ANNUAL TO PERENNIAL CROPS OVER A LARGE AREA REDUCES WORK NEEDS AND ABOLISHES NEED FOR EXTERNAL ENERGY SOURCES.

dies, waves rise from a smooth sea to signal illness, and the ti-tree breaks into flower as the swans lay their first eggs—"hurry to the lagoon, for the first eggs can be eaten, and the swans will lay again". 1.2

Virgil[10] too speaks of such things: "A heavy corn crop follows a heavy walnut crop, and a leafy corn crop the leafy walnut". The ti-tree and the walnut indicate the complexity of relationships that may exist between species. It is a wise computer which can sense such relationships, but they were the guidelines of wise men, and must be re-learnt by modern man. European or white man in Tasmania occupies just that area where the stringy bark (*Eucalyptus obliqua*) grows: he doesn't extend voluntarily beyond that range. Aboriginal tribes were limited in range by "brother" trees like the ironbark, the native cherry, or the cider gum. The tribal ecology was the ecology of that tree.

To injure a tree was to injure a brother; this outlook, then, is one of sophisticated conservation. Can you cut down a brother and live? Thus, the most important man of any tribe, chosen for long and true memory, was the crop-master. Not the chief (of warfare), not the doctor (of the spirit and flesh), but the living computer, one of a long line of accurate memories, who orchestrated the taking of food, who arranged the taboos and the prohibitions, the feasts and celebrations, and ensured that the tribal permaculture endured, even though some of the tribe itself perished. We lack crop-masters today.

2 DESIGN IN LANDSCAPE

If there is a single claim that I could make, in order to distinguish permaculture from other systems of agriculture, with the notable exception of keyline concepts, it is that permaculture is primarily a *consciously designed* agricultural system.

The main reasons for designing a plant system are:

- to save our energies in the system;
- to cope with energies entering the system from outside (sun, wind, fire);
- to arrange plants so that they assist the health and survival of other plants;
- to place all units (plants, earthworks and artifacts such as houses) in the best possible arrangement in landscape;
- to suit climate and site (specific design);
- to integrate with man and society, and save heating fuel and cooking energy; and
- to provide a wide range of necessities for man, in a way every man can achieve.

We look about in vain for evidence of good design, either in landscape or most dwellings. Landscape planners and designers are legion, but where is the evidence of their work? Apart from cosmetic and aesthetically organized plantings, following the contemplative mode of the Japanese classical gardens, or the controlled vistas of the Taj Mahal gardens, (reminiscent of the contrived and formal entries to British and American grand houses) where are we to seek functional design criteria?

The imposed zonation of functions, ranged around human settlements, and recorded by Von Thunen in his analysis of northern European settlements of the pre-industrial period has the appearance of design, but is in fact an unconscious result of the limitations of that community in its foot-and-horse-bound economy. Such arrays are the patterns forced on the people and landscape, not conscious designs chosen for their relevance to the society and to energy savings.

The formal lawns outside the courts of the Taj are maintained by a crouching group of 20-30 widows, equipped with small knives to cut the grass, and forced to this undignified labour by the need to maintain the status of (deceased) nobility, by those who admire such status. The patient hedger and gardener of Britain tugs his forelock and clips away at the hedges of the *nouveaux riches,* and the council employee tends the public parks and gardens for their public status value only. This 'design' orientation is a forcing of nature and landscape into a salute to wealth and power, and has no other purpose or function.

The only thing that such designs demonstrate is that power can force men and women and plants to waste their energies in controlled, menial and meaningless toil, much as the home gardener, in his front garden, tries to keep up a pale imitation of the same high status. But in this case, of course, he is the schizoid serf as well as the feudal lord, following his lawnmower and wielding his hedge clippers, contorting roses and privet into fanciful and meaningless topiary, as a witness to a deprived and stunted education.

Our landscapes and houses accurately reflect our world-concept and self-concept; they thus rarely show any concession to functional or utilitarian principles. Church and school grounds demonstrate the same senseless and wasteful land use, and reassure their audiences and supporters that status is all, that usefulness has neither place nor meaning in this world.

One of my favourite true stories is that of a man in Burnie (Tasmania) who dared plant cabbages on his "nature strip"—that sacred and formal area in front of his house. Having thus demonstrated his lack of the sense of fitness of things, he was sharply reminded of his error when the local council sent trucks and men to uproot the vegetables (which were merely useful, therefore of no aesthetic or design value). I must, in all fairness, say that this occurred in 1977. By 1979 the council and others nearby had tentatively commenced to plant yielding fruit and nut species in their public parks.

Granted, there are many examples of shade trees, but it is a poor tree that does not, in any case, give shade as part of its yield to man and the earth. Granted too that more sophisticated understanding of plant nutrition led to the evolution of crop rotation, or to the traditional "high

farming" of the west, which is an example of conscious design in space and time, using plants and animals in sensible succession to restore soils to health. King[5] in his book, gives many examples of the achievements of eastern peoples in labour-intensive permanent agricultures. Many of them also demonstrating great ingenuity in "stacking" plant systems for greater yield in the same area.

But a very recent book by Fukuoka[3] takes this a great step further, and beyond that described by Phillip and Young[4], who still rely on heavy applications of herbicides (mainly 2-4D) and fertilizer to achieve their no-tillage broadacre cropping of grains and pulses. Thus, there are signs of better 'plants for plants' design, and this will, no doubt, soon become more sophisticated and more widely used on economic and health grounds alone.

ON DESIGN 2·1

There are two elements to good permaculture design that are basic. The first says where we are going, the second how we get there. The first deals with principles, the management of natural elements to the advantage of man and the environment, the second is more closely allied to practical gardening and farming procedures. As examples, windbreak shape, species and placement fall under the first, and mulching, manuring, or soil improvement under the second.

Once design begins, the essentials for an ongoing evolution are:

- observation of the result; and
- control or steering to the desired end, or to a new evolution.

In complex systems, where animals and plants interact, even computers fail to cope with the number of variables, or account for the worm, the robin, the soil, and their total relationship. Only the careful human observer can cope with this sort of assessment. Quite small adjustments to the system may have the effect of turning disaster into triumph, or invasion into retreat. These are the strategies of evolution in a man-made system.

Good teachers have nothing to give but enthusiasm to learn; they cannot with the best will in the world, give their students knowledge. Thus it is design proper rather than design technique which I am concerned with here. Yeomans[2] is a master of design; Fukuoka[3] is a master of strategy.

DESIGN CRITERIA 2·2

> "Man can maximise economic and social stability by departing from monoculture of large land tracts insofar as it is possible, so that complexity of trophic food webs is maximised."
>
> —Watt [14]

Any good overall landscape design should leave options open for further refinements, so that the initial placement of structures, earthworks, and plants is so arranged that any other alternative energy system is still available for later inclusion. In short, don't cut out the sun as a source of energy, and keep the water running downhill; store it in the soil, and release it clean. Let heated air and water rise, as they will, and forget about pumps to force the reverse of natural flows.

The criteria for such designs are those that can now be applied by all landscape professionals and agricultural or architectural advisors. Not to do so is a betrayal not only of the clients, but of the future, when maintenance costs may well exceed by factors of 10 or so times the initial cost of establishing a garden, farm, parkland, home, factory or school building. Clients too need to check on these criteria:

- passive energy systems;
- adequate climate control on site;
- future developments planned;
- provision for food self-sufficiency on site;
- minimal external energy needs;
- wastes safely disposed of on site;
- low-maintenance structures and grounds;

2.2

- water supply assured, conserved; and
- fire, cold, excess heat and wind factors controlled and directed.

The simple way to check on any design is to ask "Why did you put that structure (or plant) there?"

We have reached the conclusion that any analysis of yield in permaculture needs several considerations. We have, for instance:

- product and intrinsic yields (variety and amount of crop);
- design yields (the channelling and conservation of energy);
- interaction of permaculture and other systems (dwellings) in the matter of energy transfer and conservation; and
- social and health yields.

Thus the *total* yield relies much more on our design and therefore our knowledge and intellect than it does on the energy available within the system. Even in the matter of product yield, it is our design of edge, species and placement that may determine the amount of yield, for at the edges of trial plots sampled for 'yield' the production of grain increases dramatically (Dr P. Jones, Sydney Univ. Agric. and Hort., in conversation) and it is we who determine the amount of edge in the system.

We also determine the broad arrangement of species relative to sun and wind energies, and our level of use of the system. In total, the energy saved, generated and conserved is a complex calculation, and we may always see a new way to design additional yields as we evolve more complex systems. This is particularly true if we use low-grade heat from the sun, industry and power stations to increase pond and glasshouse yields of food and fuel species, instead of letting such energies run to waste.

1 Deciding Priorities

In early stages, real needs have to be met and adverse environments modified. But always:

- the first priority is planning;
- the second that of human needs;
- the third that of energy * conservation;
- and almost as a result of these, environmental modification by designs and structures.

Provision for future energy conservation systems must be left open, so that the whole site is marked out for wind, tide, water, or sun systems. Even if these cannot be implemented in the first few years, the space is 'reserved' under annual crop or short term use.

When it comes to implementation:

- the first structures and designs should be those that generate energy;
- the second, those which save energy;
- and only finally, those which consume energy.

Priorities are fairly easily settled by matching them up to a set of criteria which is currently important and often reviewed, because as time goes by, conditions change.

Later, some commercial and 'luxury' planning may be possible, after basic needs are satisfied. Very long term planning in communities could then centre on diversification and specialization into medicinal, dye, basic chemical and fuel provision. Few of us begin however, without having to borrow energy as food, fuel, medicine, or even manure.

In all our planning, the main aim should be to achieve a synergy, so that everything that can be together is put together, works together, and helps each other—"Every unit has many uses: every use is achieved in many ways"—a fail-safe system.

---

*I'm talking here of total energies, total in that they include all energies of input, processing and output. For example labour, materials, harvesting, yields, refining, transport, packaging, storage, marketing, etc., are all possible energies involved in a system (commercial).

See *Permaculture One* sect. 2.8, p. 8-9. Ref. 19, and Goldsmith (et alia), *Blueprint for Survival*, Ecologist 1972.

Applying such criteria, many questions will answer themselves, for example:

Where should I build my glasshouse?

On consideration of energy alone, the answers are obvious:
- first, against dwellings as heat sources and stores, and to grow food;
- second, against non-dwelling structures, as heat sources;
- thirdly, as part of animal housing, with heat, manure and gas exchange;
- and only finally, or perhaps never in sensible terms, as free-standing, all-glazed structures.

How should I deal with wind which prevents my growing on site?

- First, by planting any tree or shrub, useful or not (wormwood, pampas, pine, coprosma, thorn) that is cheap or free locally, grows very quickly, can be quickset or grown from large rooted cuttings or divisions, and that will *survive;*
- second, by structures, especially trellis, loose or dry-stone wall, ditch, bank, and small hedgerow throughout the garden;
- third, by broadscale quickset or seedling planting of hardy species;
- and lastly, by useful permanent hedge planted under the protection of the above strategies.

What is worth main-cropping?

Only a few plant species are worth extensive main cropping. Ignoring the commercial value for the moment, there are three main considerations:
1 main crop which needs little attention after establishment (potatoes, corn, pumpkin);
2 and which is easy to harvest, store and use;
3 also, may form a staple in diet.
Thus, potatoes, corn, pumpkin (for seed and flesh) again. Grain only if grown in small plots on the Fukuoka[3] system.

Commercially, we should also consider crops of:

4 high economic value, even if they are difficult to harvest (strawberries, raspberries);
5 or hard to keep (melons, peaches);
6 or rare but in wide demand, (ginseng, asparagus);
7 or particularly suited to site (cactus, fig, water chestnut, cranberry), say a gentle slope to the north where few variables are encountered. "Real" landscape is dealt with in following sections.

About the same criteria should apply to tree crops; they can always be interplanted with annual crop while time passes, thus in the above number series:
1 would be plums, hardy fruits and vines;
2 would be nuts and easily dried fruits;
3 would be nuts again, and high food value fruits;
4 would be cherries, crocus for saffron;
5 would be 'local' soft fruits like paw-paw, raspberries;
6 would be spices and medicines, dyes, and oils;
7 would be sugar maple, cider gum, pistachios, etc.

In the realm of practical, on-the-ground design, we are very often working without any precedents, and in these cases common sense, observation, good research into species, and the necessary physical principles are our only guides. But the designer should ever be alert to local phenomena and special features, endeavouring to turn what is already in place to advantage, rather than to bring in new structures, and hence, new energy.

2·3 ZONE AND SECTOR GROUND PLANNING

(See also pp. 49-57 in *Permaculture One*)

The whole key to efficient energy planning (which is, in fact, efficient economic planning) is the zonation and radial or sectoral placement of plants, animal ranges, and structures. The only modifiers are local factors of market, transport routes (access), slope, local climatic quirks, areas of special interest, such as flood plains or rocky hillsides, and special soil conditions, such as hard laterites or swamp soils. As all of these local effects are dealt with later, I shall concentrate here on the way to zone and plan for an "ideal" site, say, a gentle slope to the north where few variables are encountered. "Real" landscape is dealt with in the following sections.

Table 2.1 Some factors which change in zone planning as distance increases.

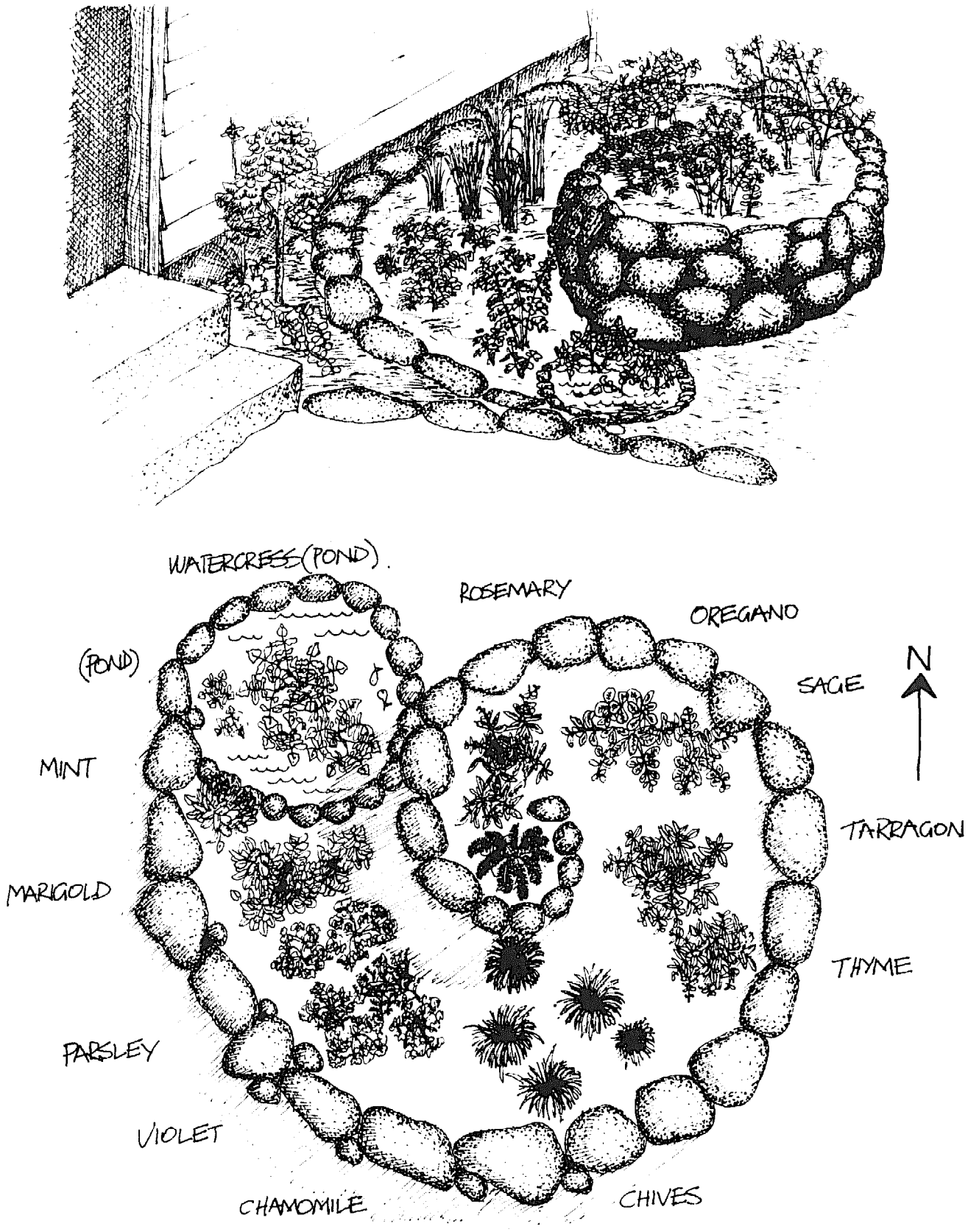
Factor or Strategy	Zone I	Zone II	Zone III	Zone IV
Main design for:	House climate Domestic sufficiency	Small domestic stock and orchard	Main crop, forage, stored food	Gathering, forage, forestry, pasture
Establishment of plants	Complete sheet mulch	Spot mulch and tree guards	Soil conditioning and green mulch	Soil conditioning only
Pruning of trees	Intensive cup or espalier, trellis	Pyramid and built trellis	Unpruned and natural trellis	Seedlings, thinned to selected varieties
Selection of trees and plants	selected dwarf or multi-graft	Grafted varieties	Selected seedlings for later grafts	Thinned to selected varieties, or managed by browse
Water provision	Rainwater tanks, well, bore, reticulation	Earth tank and fire control	Water storage in soils, dams	Dams, rivers, bores, and wind pumps
Structures	House/glasshouse, storage integration	Greenhouse and barns, poultry sheds	Feed store, Field shelter.	Field shelter grown as hedgerow and woodlot

1 How to Place Elements in Zones

Now, there is no doubt at all that the place to start is at the doorstep.
If you do not have the doorstep controlled, there is not much hope for the back paddock, or the back fence.

Zoning, (distance from centre) is decided on two factors:
(a) the number of times you need to visit the plant, animal or structure;
(b) the number of times the plant, animal or structure needs you to visit it.
For example, on a yearly basis, we might visit the poultry shed:

- for eggs, 365 times;
- for manure, 20 times;
- for watering, 50 times;
- for culling, 5 times;
- other, 20 times.



FIG·2·1: SPIRAL RAMP FOR CULINARY HERBS · AT KITCHEN DOOR. (3M. DIA.)
(PLAN)

2.3 Total = 460 visits; whereas one might visit an oak tree twice only, to collect acorns. Thus the zones are "frequency zones for visits, or "time" zones, however you like to define them. The more visits needed, the closer the objects need to be. As another example, you need a fresh lemon 60-100 times a year, but the tree needs you only 6-12 times a year, a total of 66 to 112 times. For an apple tree, where gathering is less, the total may be 15 times visited.

Beginning from the backyard again, we can range out from the doorstep as follows:

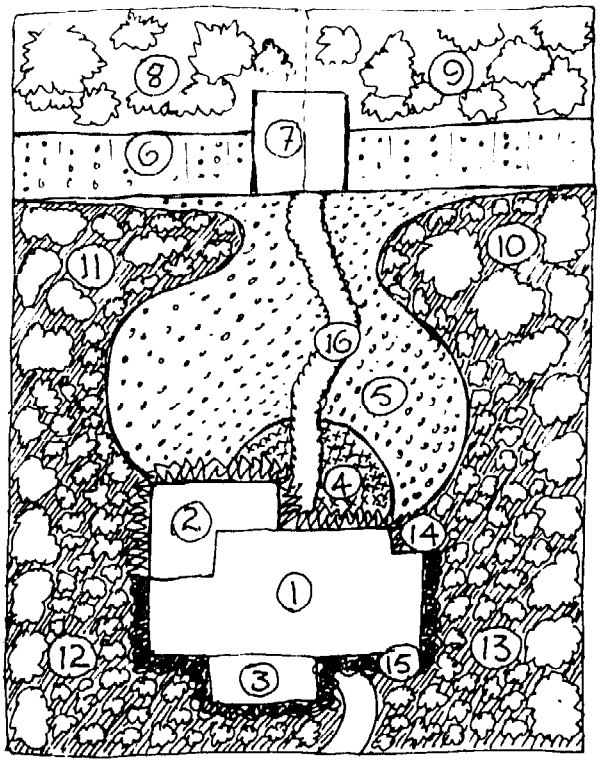

1 HOUSE: BEDROOMS TO S., LIVING ROOMS TO N.
2 SHADEHOUSE: COOL AIR SOURCE.
3 GLASSHOUSE: HOT AIR SOURCE AND HEAT PUMP.
4 KITCHEN HERB GARDEN.
5 ANNUAL GARDEN (TO 6)
6 "CHICKEN TRACTOR" GARDEN
7 CHICKEN HEATED GLASSHOUSE.
8+9 STRAWYARDS FOR ALTERNATIVE USE, FORAGE FOREST FOR POULTRY.
10 LARGER FRUIT SPECIES (EVERGREENS TO N.)
11 AS FOR 10. SMALL FRUIT AND LARGE HERBACEOUS PERENNIALS EDGE ANNUALS.
12+13 LOW SMALL FRUIT, NUT, PRUNED TREE SPECIES, LARGER AT BOUNDARIES.
14 EVERGREEN VINES ATTACHED TO, OR TRELLISED NEAR HOUSE TO S. FOR WINTER INSULATION.
15 DECIDUOUS VINE TO N. FOR SUMMER HEAT CONTROL, GLASSHOUSE SHADE.
16 COVERED WALKWAY OR ARBOUR WITH VINE CROP, POLE BEANS.
N

FIG. 2.2: DESIGN FOR ¼ ACRE BLOCK (PLAN).

or, on a larger scale, a small farm (See Fig. 2.3)

The golden rule is to develop the nearest area first, get it under control, and then expand the perimeter. Too often, the novice selects a garden away from the house, and neither reaps the plants efficiently, nor cares for them well enough. Any soil gives a good garden, so stay close to the home.

Stabilization and utilization of landscape is a moral issue with global implications. The sight of poverty-stricken nomads following huge goat flocks is an end-game in the environmental management strategy, as is a row of harvesting machines, a rabbiter with a pack of mongrel dogs, and giant logging trucks. All are variations on the theme of biological extinction.

It is our firm belief that if one cannot maintain or improve a system one should leave it alone, thus minimising damage and preserving complexity. If we do not regulate our own numbers and appetites, and the area we occupy, nature will do so for us, by famine, erosion, poverty and disease. What we call political and economic systems stand or fall on our ability to conserve the natural environment. Closer regulation of available land plus very cautious use of natural systems is our only sustainable future strategy. Perhaps we should control only those areas we can establish, maintain and harvest by small technologies as a form of government on ourselves, and our appetites. This predicates that settlements should always include total food provision, or else we risk the double jeopardy of sterile city and delinquent landscape, a fatal combination, where city, forest and farm are all neglected and lack even the basic resources for self-sufficiency.

Time, like area, is a resource (as any farmer knows). Just as we can over-extend in area, so we can in time. This is the very basis of zonation planning in permaculture; it becomes critical as a matter of time conservation, to tend to the land nearest to one, not to commute too far, and thus centralise on settlement. Very close attention should be given to the nature of activities and distance, or we may run out of time for control, and hence lose yield and stability. 2.3

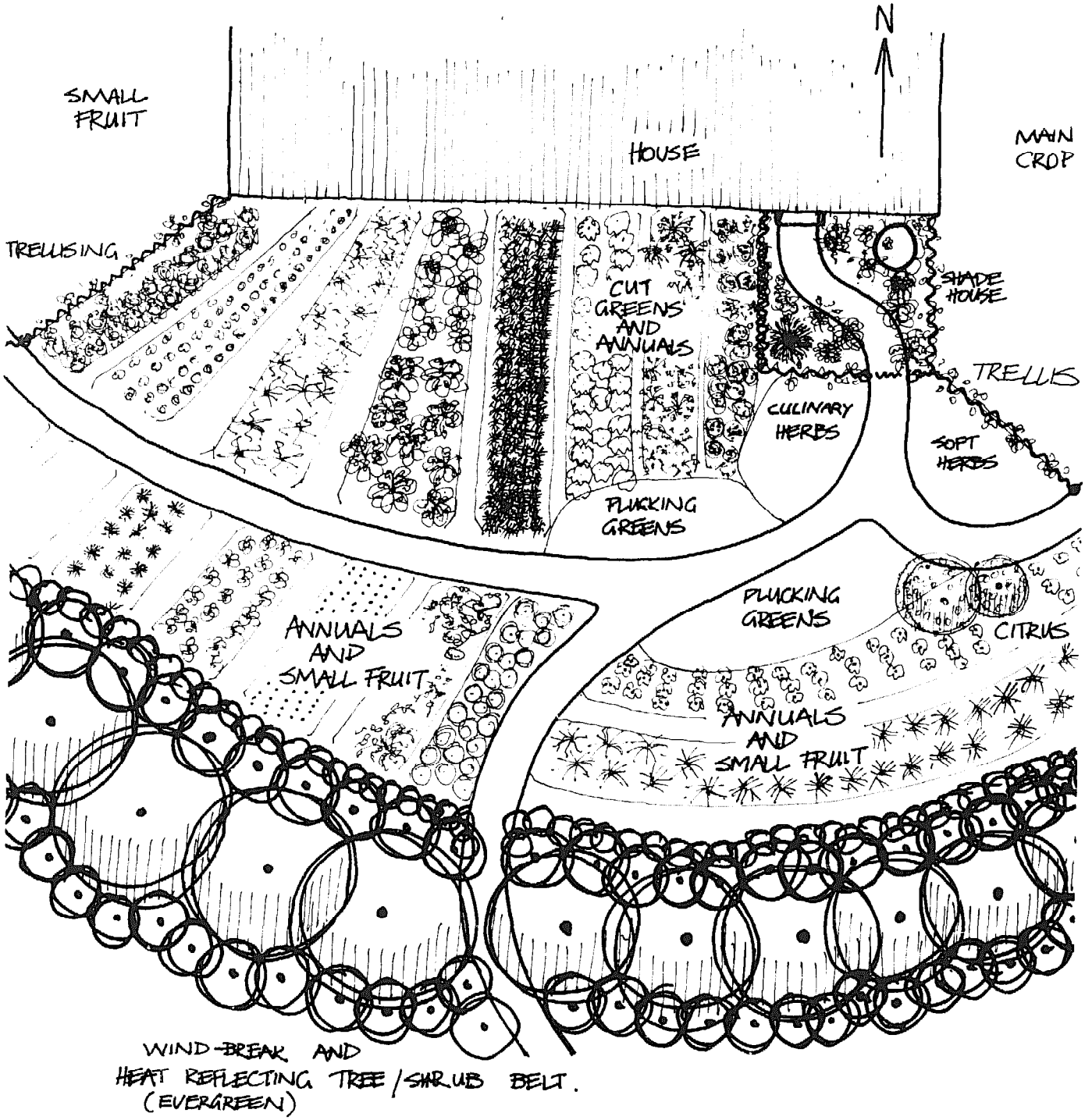


FIG.2.3: ZONE PLACEMENT OUT FROM KITCHEN DOOR. (DETAIL OF FIG.2.2.5).

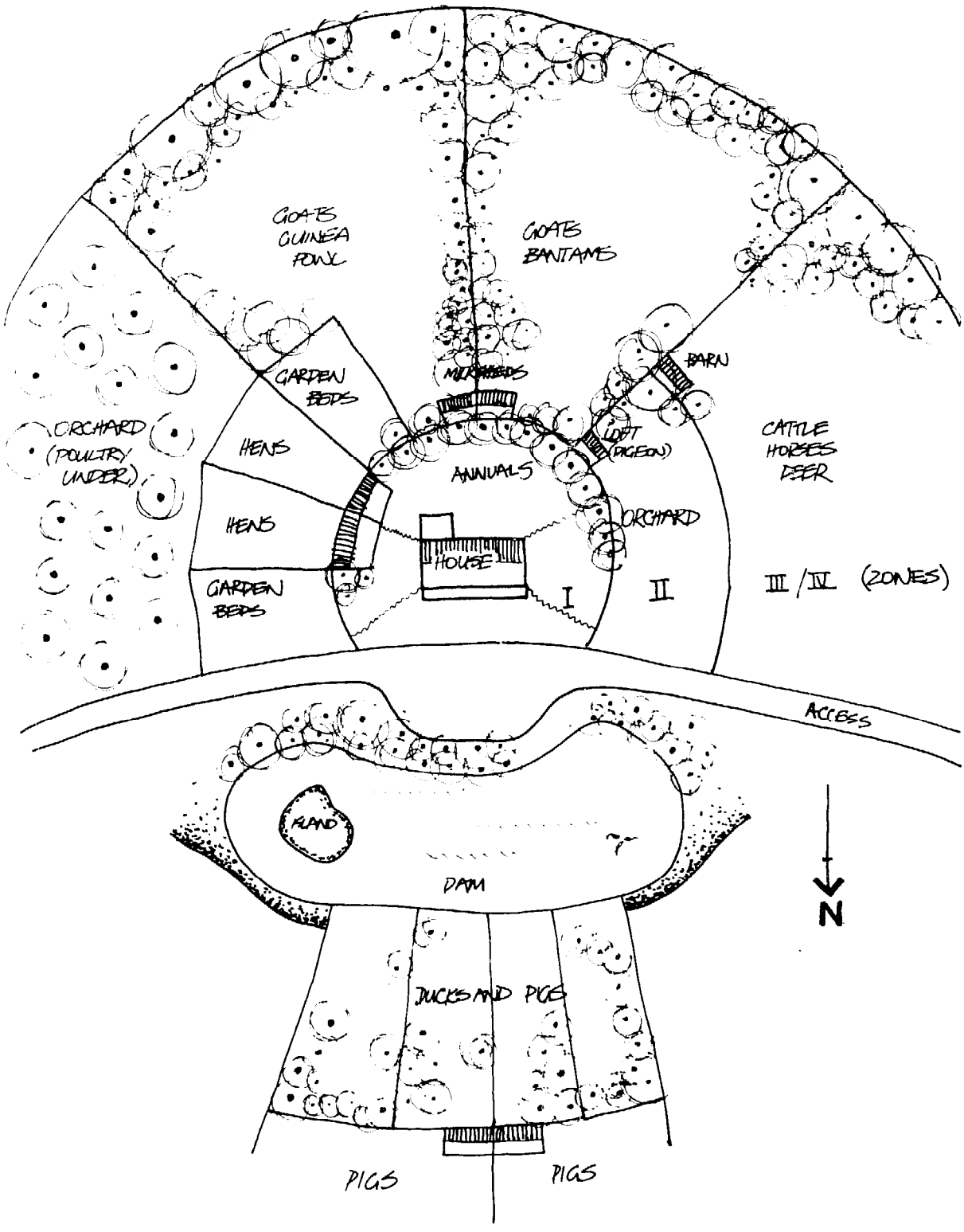
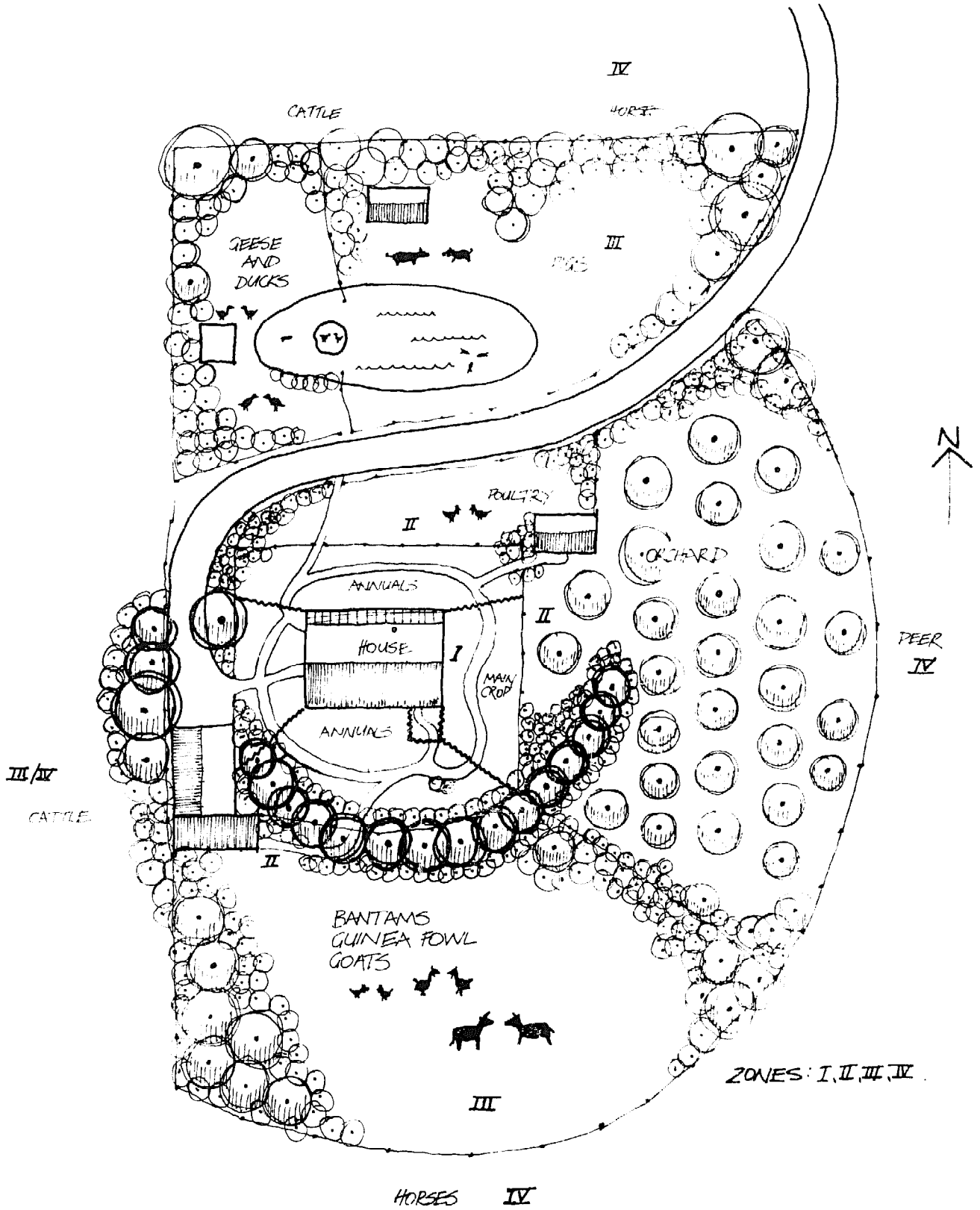


FIG. 2.4: SCHEMATIC PLAN FOR LIVESTOCK RANGE AROUND HOUSE (5-500 A)



GROUNDPLAN FOR MIXED SMALL FARM DESIGN FIG 2.5

2 How to Place Elements in Sectors

Sector planning is also dealt with in Permaculture One.[1] The factors to sketch out on a ground plan are:

- fire danger sector
- cold winds
- hot, salty, or dusty winds
- screening of nearby irksome views
- winter and summer sun angles and
- reflection from ponds.

With zones and sectors sketched in on the ground plan, slope analysis may proceed. High and low entries or access roads, the former for heavy cargo or mulch, the latter for fire control, can now be placed. Provision for attached glasshouse, hot air collector, reflection pond, solar pond, and shadehouse should be made at all homestead sites where climatic variation is experienced. Details of these are given in following sections.

Now, to sum up, there should be no tree, plant, structure, or activity that is not placed according to the criteria and the ground plan. For instance, if we have a pine tree, it goes in Zone IV (infrequent visits), *away* from the fire danger sector (it accumulates fuel and burns like a tar barrel), *towards* cold wind sector (pines are hardy wind breaks), and it should bear edible nuts as forage.

Again, if we want to place a small structure such as a poultry shed, it should border Zone I (for frequent visits), be *away* from the fire sector, *border* the annual garden (for easy manure collection), *back onto* the forage system, possibly *attach* to a greenhouse, and form part of a windbreak system.

There is no mystery nor any great problems in such commonsense design systems. It is a matter of quietly bringing to consciousness the essential factors of passive planning. To restate the basic energy-conserving rules:

- "No placement without the element (plant, animal or structure) serving at least two or more functions".
- "Every function (water collection, fire protection) served in two or more ways."

With the foregoing rules, strategies, and criteria in mind, you can't go far wrong in design.

2·4 BROADSCALE LANDSCAPE ANALYSIS

"Look!—from the hilltop he coaxes water out of its course, and it slides over smooth pebbles whispering hoarsely and soothes the parched field with its purling."

—Virgil[10]

Fig. 2.6 shows a broad landscape profile, typical of many humid tropical to cool climates, which we can use as a model to demonstrate some of the principles of landscape analysis. The high plateaus (A) or upper erosion surface, where snow is stored, trees and shrubs prevent quick run-off, and where the headwaters of streams seek to make sense of a sometimes indefinite slope pattern, gives way to the steep upper slopes (B), rarely (or catastrophically) of use to agriculture *per se,* but often cleared of protecting forest and subject to erosion because of this.

The lower slopes (C) are potentially very productive mixed agricultural areas, and well suited to the structures of man, his domestic animals, and his implements. Below this are the gently-descending foothills and plains (D) where cheap water storage is available as large shallow dams, and extensive cropping can take place.

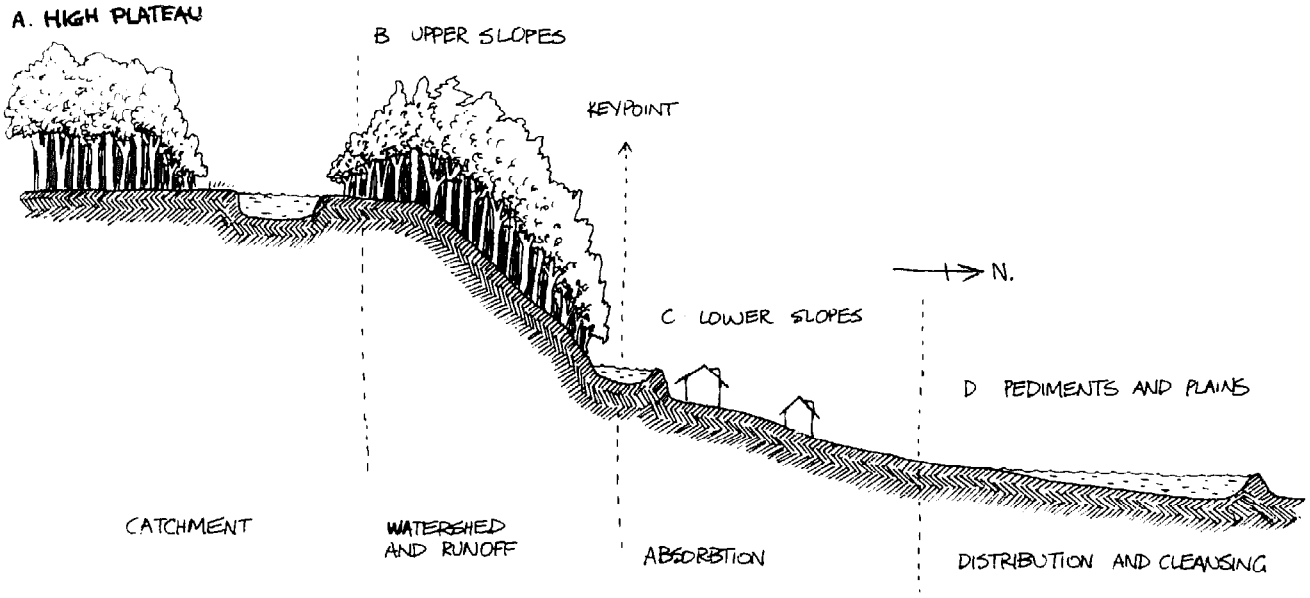
This simplified landscape should itself dictate several strategies for permanent use, and demands of us a careful analysis of techniques to be used on each area.

The main concern is water, as it is both the chief agent of erosion and the source of life in plants and animals. Thus the high plateau is a vast roof where rain and snow gather, winds carry saturated cloud to great heights, and at night the saturated air deposits droplets on the myriad

leaves and surfaces of plants. Prof. W. D. Jackson, (Univ. of Tas., in conversation) by using condensation screens on high humid lands, estimates that perhaps 85% of precipitation condenses from the night air on the myriad leaf surfaces of the plateaus. 2.4

Trickling down, this moisture needs soft soils and humus to retain it and govern the floods and droughts that plague barren landscapes. Rocks, if covered by soil and plants, do not release so much salt into the water, and trees act as pumps which keep the water table from surfacing on the plains and so creating salt pans.

Such fragile systems, often precariously in balance because of slow plant growth, must be guarded from over-grazing and soil loss if most water is to be saved for power generation and agriculture lower down. The best usage is therefore careful husbandry of all elements, and a watch on delinquent usage; it involves the management or culling of severe browsers (as for deer in New Zealand), and the planting or maintenance of as many trees, shrubs and ground cover as possible to trap and hold moisture. Of all areas, this high catchment is the most critical to the national or continental well-being. Vandalism by ski-resort developers, high-country graziers and public "authorities" should be reduced to a minimum.



DOWNSLOPE — IDEALIZED LANDSCAPE PROFILE. FIG.2·6

The high slopes (B) are of next importance to the general hydrological cycle, and it is in clearing these that most countries come undone; for the trees that occupy these areas are the groundwater pumps that prevent the rise of salted water to the surface downslope and thus the salting of soils. The upper-slope forests are essential to man, reducing cold air flow and the erosion that fills the lower valleys, thus converting rivers to quagmires and lakes to peat bogs, as has happened in Europe and Asia.

A moratorium on all clearing or grazing of slopes of 18° or more should be an international concern, of as much long-term importance as a moratorium on arms. Re-afforestation of slopes with useful forage and fuel trees, their cautious use by man and his animals, and permanent forests as buffers to area (C) are the only moral use of steep slopes.

Where we venture (as in Nepal) to clear and terrace such systems, graze off the regrowth, and attempt the only subsistence left to us (grain terrace culture) catastrophe awaits us. The aerial view of denuded foothills and valleys that stretch from Yugoslavia to Bengal, the deserts evolving below them, and the plight of the people pinned into the valley floors, are a witness to our lack of comprehension of economies and nations. Here, as in North Africa, man and his goats are the plague, locusts and deserts follow. World hunger for paper, particularly wrapping paper and

2.4 newspaper will only accelerate world famine for food. Even in countries still rich in foothill forests, as in the "developed" world, the same fate awaits as has overtaken the "underdeveloped" world. We would do better to characterise these as the devastated, defoliated or stripped ecologies, and those about to be stripped. In West Australia recently a man was gaoled for attempting to blow up a woodchip plant; his act is seen by society as immoral, while the plant owners, safe in their offices, are unmoved by the devastation they create, protected by the laws of property, and are, in the long term, the greater vandals. No nation that now exists has environmental laws as strong as those that protect the exploiter.

This may change when people see clearly the environmental traps that await them: when the agriculturalist on the plains of Swan Hill, surveying his salting fields lifts his eyes to the foothills and asks of his fellows what they are doing to the forests that once protected him; of his local council why men paid by public money are clearing the roadsides of trees, and of his state government why a woodchip development is underway upslope.

The gentle foothill country of area (C), brilliantly analysed for water conservation by Yeomans[2], supports the most viable agricultures, where the forest above still exists. Here, the high runoff can be led to midslope storage dams at the "keypoint" indicated in Fig. 2.6 (examined in much more detail in Yeomans' books). Using the high slopes as watershed, and a series of diversion catchment drains as "spouting" and dams as "tanks", water is conserved at the keypoints for later frugal use in fields and buildings, is passed with its nutrients to low dams, and released as clean water from the site. (This is the ideal: the reality often falls far short of it.) The lower slopes, those safe to use tractors on at least, can be converted to immense soil-water storage systems in a very short time (a single summer often suffices). Some data is given in Sections 3 and 7, but Yeomans' books are the best detailed guide.

Slope gives immense planning advantages; there is hardly a viable human settlement (not supported by the failing petrol economy) that is not sited on those critical junctions of two natural economies, here the area between foothill forest and plains, elsewhere on the edge of plain and marsh, land and estuary, or some combination of all of these. Planners who place a housing settlement in a plain, or on a plateau, may have the 'advantage' of plain planning, but abandon the inhabitants to failure if transport fuels dry up, when they have to depend on the natural environment for their varied needs but have only a monocultural landscape. Successful and permanent settlements have always been able to draw from the resources of at least two environments. Similarly, any settlement which fails to *preserve* natural benefits, and, for example, clears all forests, is bent on eventual extinction.

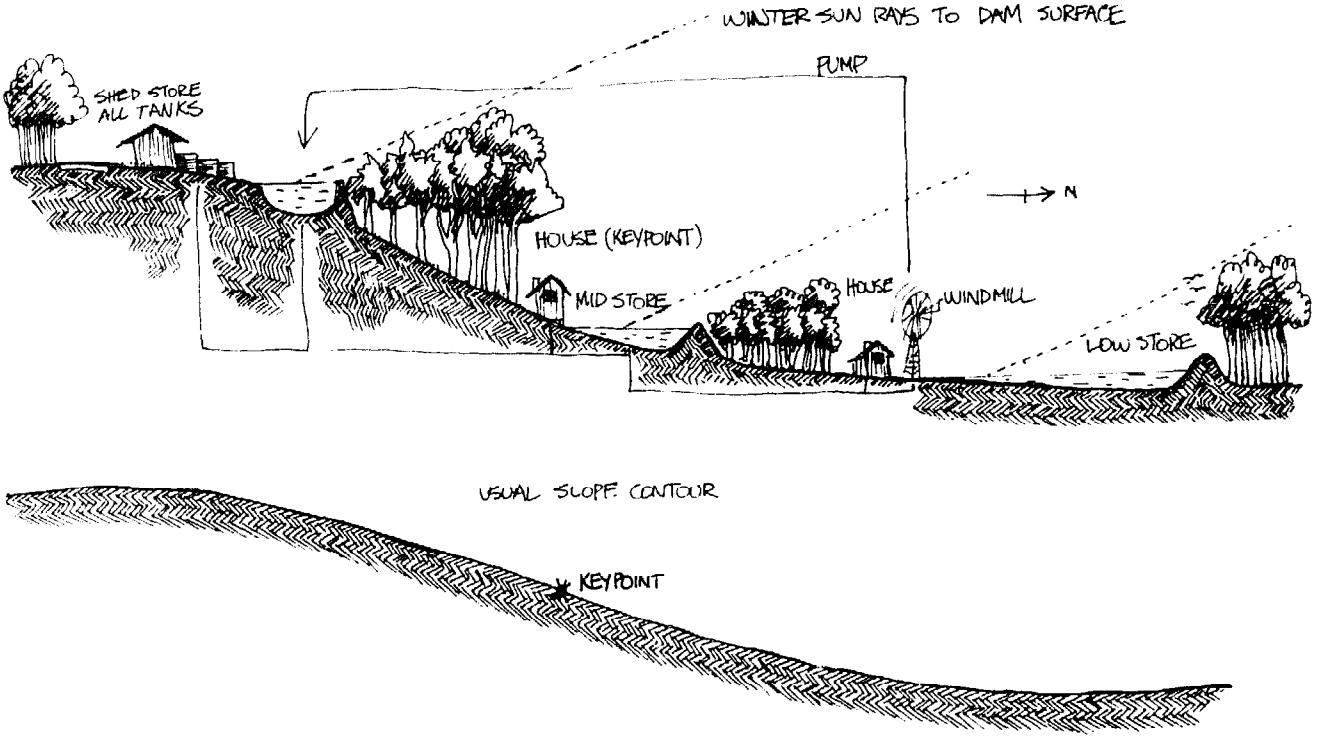
The easy, rounded ridges of non-eroded lower slopes and their foothill pediments are a prime site for settlement. They allow filtration of wastes, inseparable from large populations, through lowland forest and lake, and the conversion of toxic wastes into useful timber, trees, fruits, and aquatic life. (Fig. 2.7).

The descending slopes allow a variety of aspects, exposures, insolation, and shelter for man to manage, and give responsible planners all these advantages to design with. Midslope is our easiest environment, the shelter of forests at our back, the view over lake and plain, and the sun striking in on the tiers of productive trees above and below. The ancient occupied 'ridgeways' of England testify to the commonsense of the megalithic peoples in landscape planning, but their present abandonment for industrial suburbs in flatlands does little credit to the paleolithic planning of modern designers. The difference may be that the former planned for themselves, the latter do designs for other people.

The plains of area (D) are the most resistant to water damage (except for evaporated salt), and the most open to wind erosion. The red and dusty rains and the plagues of locusts that fall on all nearby lands are a result of the delinquent use of the plough, heavy machinery, and clean tillage of these flattish lands, together with the removal of trees and hedgerows, and the conversion of the plains to a monoculture of extensive grazing and grain cropping. It is here that water is most cheaply stored, in soil and in large surface dams, where no-tillage crops, copses and hedgerows are desperately needed; and where broad-scale revolutions in technique can be implemented to improve soil health, reduce wind and water losses, and produce healthy foods.

Even on the arable lands, and especially in tropical areas, scattered leguminous trees (at about 10-12 per ha.) greatly assist in nutrient recycling and soil stability (see Poulsen[17]), so that cropland should present the appearance of a scattered forest with copses, rather than that of a windswept plain. 2.4

So much for the very broadscale analysis, although the same sense applies to any small property that includes a reasonable slope. Local modifications are to use the flat plateaus at midslope, or the flattish tops of minor ridges as fields and pasture.



IDEAL PLACEMENT OF ELEMENTS IN RELATION TO SLOPE: FIG.2.7

Taking Advantage of Slope 1

(Farms and small settlements)

Figs. 2.7 and 2.8 illustrate some ideal relationships of structures and functions, given that there is a reasonable slope. Starting from the plateau or ridge:

"Turkey nests", or storage dams, can be placed here to take overflow from high tanks, which rely on the roof catchment of barns, workshops, stores, meeting halls, etc., all of which consume little water but have large roof areas for catchment. Diversion channels around high ridges serve the same purpose.

In emergencies such as fire or drought water from the valley lake or large-volume storage at lower levels can be pumped to the higher tanks or dams. All covered tanks at this high level are very useful, and these can in fact be built as the basement or foundation of the buildings, thus forming a heat/cold buffer in the sub-floor of workshops. A small standby fire pump, or a mobile fire pump can use these in emergencies. Water from covered tanks is guaranteed free of biological pollution, and should be reserved strictly for drinking water at lower levels, the settlement area.

Bulk domestic water (showers, toilets, etc.) can be supplied from the high dams on the keyline,

2.4 or above it. These can be refilled where needed from the valley dam, and used on the midslope gardens.

Above the keyline, particularly on rough, rocky and dry sites, there should be careful selection of dry-country permaculture needing 'spot' watering only for establishment. On lower sites choose plants with higher water requirements (see also Fig. 5.3).

At the dwellings, small tanks for emergency supply are needed (ca. 22,000 l for a family of 5) and the dwelling sited behind the lower dams or lakes for fire protection (fire is most intense when advancing upslope). Waste water, run to a series of small pondings, provides valuable algae and nutrients for low gardens, duck food, and fish food.

A factor often left unplanned is the high slope access, either as track or road. Such access can embody drainage or diversion to midslope dams, fire control on slopes, and cargo or harvest-time access to forest and to service buildings. Often enough, on small properties, the mulch and manures from high barns and forests can be easily moved downhill to establish the barn-to-house garden. Slatted floors under upslope shearing sheds, goatsheds, and stables enable dry storage and easy access to manures.

The forests on the high slopes, coupled with the "thermal belt" (see *Permaculture One*) of the house site make a remarkable difference to midslope climate and soil temperatures. Anyone who doubts this should walk towards an uphill forest on a frosty night, and measure or experience the warm down-draught from high forests. If these are above Zones I and II, they present little or no fire danger. Their other functions of erosion control and water retention are well attested.

Downslope, reflection from dams (detailed in *Permaculture One*) adds to the warmth. Solar collectors placed here transmit heat, as air or water circulating by thermal siphoning alone, and assist house, glasshouse or garden to function more efficiently. Even very slight slopes of 1 : 150 or so, function to collect water and heat if well used in design.

While the foregoing sections set the design background, the actual techniques and strategies of each system are discussed in following sections, and it then remains to fit together the jigsaw of design using these techniques in establishment and maintenance.

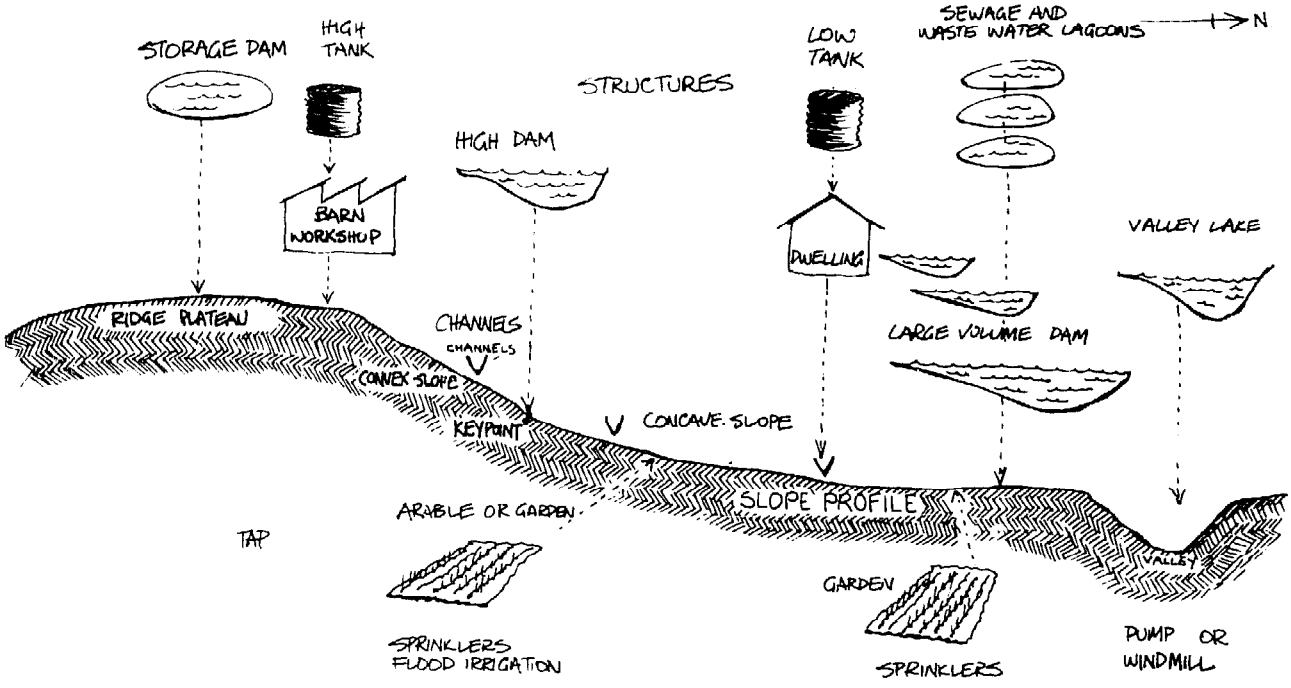
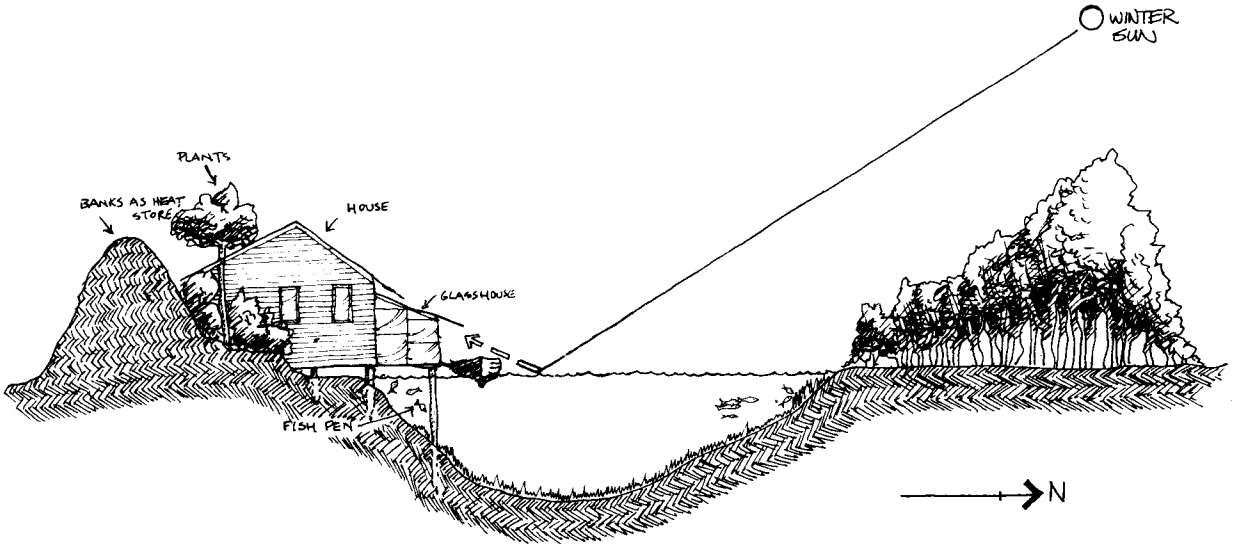
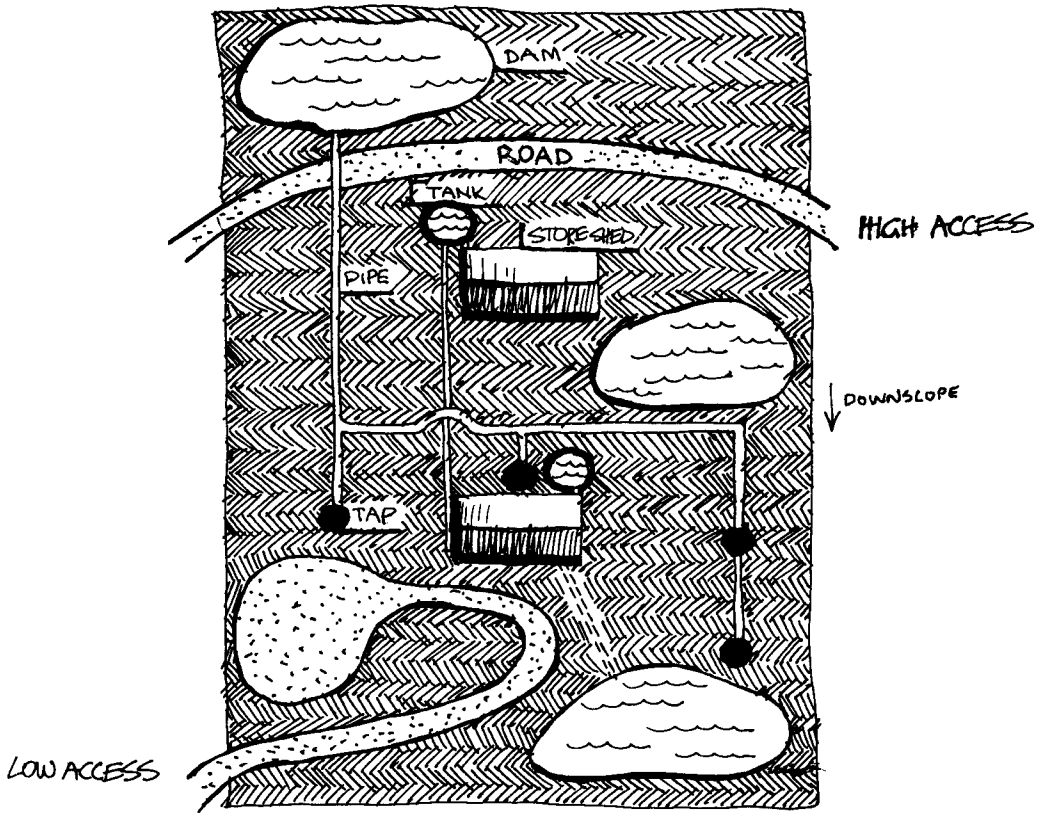


FIG. 2.8: IDEAL RELATIONSHIPS OF STRUCTURES AND WATER STORAGES ON SLOPES (FUNCTIONS AND USES).



DAMS AS WINTER SUN REFLECTORS WILL INCREASE DAWN, EVENING OR WINTER HEAT ON BANKS TO S(N). GLASSHOUSE, PLANTS SITED THERE ALL BENEFIT

· FIG. 2·9



IDEALIZED. DOWNSLOPE LAYOUT OF WATER, BUILDINGS, ACCESS. FIG. 2·10:

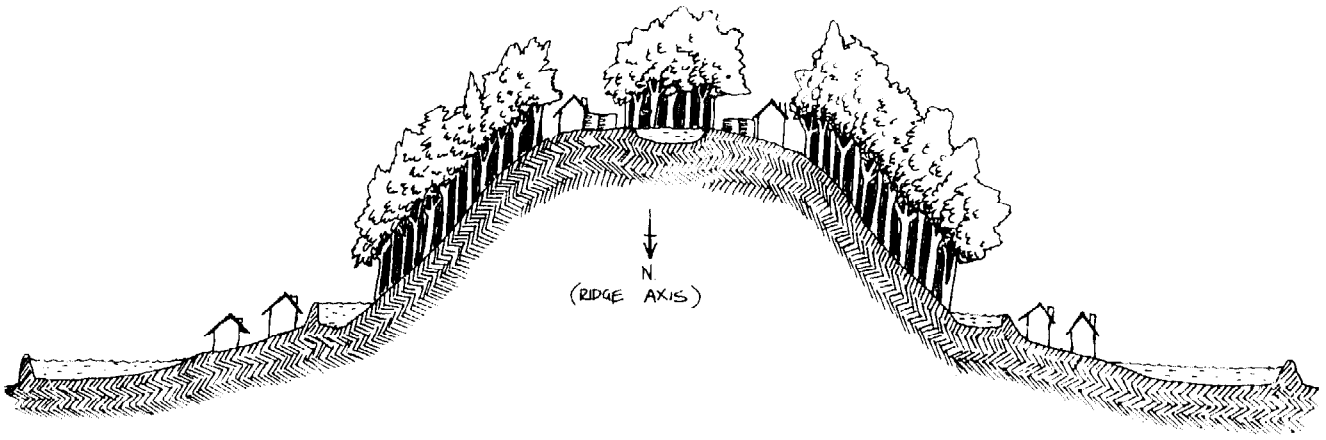


FIG. 2.11: CROSS-SLOPE IDEALIZED LANDSCAPE PROFILE.

2·5 HOW MUCH LAND?

"admire a large estate if you like: but farm a small one."
—Virgil[10]

We have made perhaps the gravest, or greediest, error of them all: we have over-reached ourselves. On the farmlands of the northwest coast of Tasmania they speak of a man with too much land as "land poor", and he will become the poorer as his holdings increase somewhat like the greedy fisherman, who catches fish until more fall overboard than he lands. If we could adjust land to our age, we might be thought of as wise, but we tend to get more land as we get older, and to treat it less kindly. The whole earth demonstrates the neglect of husbandry, and the greed of men for land. Companies too are discovering that large holdings are large liabilities, and these will become even more so as the petrol pool dries up. Friends recently returned from China, where 45,000 people existed in a healthy state on some 8000 ha, to find their son in Australia going broke on the same area!

People frequently ask how much land they need for self-sufficiency. The answer is, "As much as you can control". Any more and you lose self-sufficiency, let alone the ability to produce an excess. If people ask "Where do I start?" then the answer is always "At your doorstep".

If you see a farm where the doorstep leads to weeds, then the weeds will go to the boundary; it is already out of control. Anybody, farmer or suburbanite, that has not planted a garden at the back doorstep hasn't started a permaculture. If 4% of land, that small area around peasant houses in Russia, produces 60% of the food, what would happen if the peasants were given 8% of the land? It is that small plot not far from the house that is the most important area to cultivate. For the farmer, it may mean all the difference as to whether or not he can stay on the farm and survive market and energy fluctuations. For the suburbanite, it may mean the difference between survival in comfort or misery.

There is probably some ideal plot, about 750-1000 m^2, for the home garden, if one is thinking in terms of annual agriculture. Less means too little food, more means too much land to control. But the smaller the managed annual system can become, the more is left for perennial planting and for free-range animals on forage crop.

What we observe in the western world is a delinquent landscape—the suburban plots under lawns and cosmetic flowers, and areas of urban blight around cities, more land cleared at the frontier, and a desperate misuse of land in between. This system is not, in any future terms, sustainable.

At this moment, it seems clear that planning for high labour-intensive food production at the doorstep is the only way out of future crises. Vegetables can largely supplant monoculture grains for human food, as tree crops can largely supplant grains for animal forage. The energy savings of both these strategies are obvious and necessary.

THE STACKING OF PLANTS 2·6

"The long serpentine trunks of the palm tree rise above every village and about every field. The fibrous palm has entered almost every facet of the peoples' lives. It is the first line of defence against the sun in the open fields, and in its shade grows the olive tree.

Under the olive, the fig grows, and under the fig, the pomegranate and vine, then the grain and vegetables. The palm tree's second contribution is dates . . ."

—Williams[9]

This evocative quote might as well head the section on arid lands, but it is the essential prelude to consideration of multi-tier agriculture, especially where fierce sun is the enemy. Williams does not intend to present the picture of a forest, where crowded and overshaded plants do not receive enough light or moisture, but rather one like that portrayed in Fig. 2.12.

My friend Neil Douglas, who gardens like an earth spirit on the shale hillside of summer-droughted Victorian foothills, raises his vines such as pumpkin and beans and places his trees to cast shade on, rather than to compete with, the myriad plant species which riot in his garden. The illustrations in *A Book of Earthly Delights* (Abbie Heathcote, Compendium, 1978) show clearly how the garden is structured—ecologically rather than anarchistically, but with an order that is evolved more than impressed. Such gardens arrive after some years of trials, where species themselves indicate their preferences, often in defiance of the dictates of literature. It is fortunate indeed that plants cannot read!

In nature, the rigours of the environment may decide the spacing of plants, the degree of "stacking" or density of plants. The main limitation may be set by rainfall, and in the desert or semi-desert there are large areas of bare ground between plants.

System Establishment 1

It is not difficult to accommodate or design gardens that are more intensive than the natural system, and our advantage is that we can use several strategies to increase the number of plants that will fit into an area. These are:

- by preventing water loss, building high shade, or hedge and trenched wall systems which reduce evaporation by wind;
- by introducing very drought-resistant species such as cacti, which have a greater resistance to drought than normal useful plants, especially as windbreak hedges; and
- by using vertical, buried sheet-plastic moisture barriers between the garden and the dry soil it adjoins.

Our ability to take advantage of all the species and cultivars utilized and developed by man in other places, or at other times, depends directly on our ability to provide the situation (niche) suited to them. Hence the rationale of modifying existing natural systems or buildings.

"An environment can in this way be made to accommodate many species without competition between them." (Watt[14]). The main modification, and it is a very important one, is that a well-occupied system resists invasion by rampant forms (such as blackbirds and blackberries), so that the initial diversity, plus lack of disturbance are the factors that will preserve the diversity-stability dynamism. I cannot stress too much the importance of keeping a small area fully occupied with plants, as a strategy to reduce work.

It is only at the point that the system begins to "simplify" itself that we need to move in. As a rough guess, this would need to be at about 60 years for long-lived and large elements, and at increasingly shorter periods for small or short-lived elements. There is no reason, however, why some elements and many structures should not persist for millennia, and the preservation of 'edge'* maintains our choice and the persistence of smaller, short-lived and open-situation species.

FIG.2·12: WILLIAMS' WORD PICTURE OF NILOTIC AGRICULTURAL TIERS. PALMS CAST SHADE OVER OTHER CROPS BUT, ALL ELEMENTS WHERE WATER IS LACKING MUST BE WIDELY SPACED. AS HIS PHOTOGRAPHS SHOW, IRRIGATED CROPLAND HAS FEW TREES.

2·7 THE INTERACTION OF PLANTS AND ANIMALS

The trouble with good books on gardening is that they often treat each species as though it lived alone. Notable exceptions exist in, for instance, the literature on companion plants, and in isolated papers on plant antagonists. Even to ennumerate some of the inter-relationships between plants would be a help. Plants then:

- act as trellis to plants (grape on mulberry, fig, boxthorn);
- screen and shade plants (coffee under palms);
- provide nutrients to plants (comfrey leaves for potato sets);
- cross-fertilize plants (different varieties of plums and nuts);
- live in obligate relationships with plants (fungi under oaks, pines);
- reject or accept other plants (see section on companion plants);
- provide spare parts (grafts) for plants (apple, pear, nut species).

*The "edge effect" is an important factor in permaculture. It is recognised by ecologists that the interface between two ecosystems represents a third, more complex system which combines both. At interfaces species from both systems can exist and the edge also supports its own species in many cases. Gross photosynthetic production is higher at interfaces. For example, the complex systems of land/ocean interfaces—such as estuaries and coral reefs—shows the highest production per unit area, of any of the major ecosystems (Kormondy, E. J., *Concepts of Ecology*. Prentice Hall, New Jersey, 1959). A landscape with complex edge is interesting and beautiful; it can be considered the basis of the art of landscape design. And most cerainly, increased edge makes for a more productive landscape. (*Permaculture One*', p. 29).

Similar lists can be made for plant-animal, and plant-inorganic element relationships. Obviously, some of these relationships (e.g. grafting) are functions used by dedicated gardeners. Others (nutrient provision) may be the very stuff of permanent agriculture and regional sufficiency. Lawrence Hill's painful warning on the possible dangers of eating comfrey (*New Ecologist,* 1979) stresses the other uses of such a plant, as a handy liquid or trenched manure, or in medicine. Leucaena, lucerne, and in truth, most legumes (Sect. 3.2) provide essential elements, as may any vigorous and deep-rooted weed or tree which probes the soil below the leached upper levels. All material in nature cycles *via* wind, water, dust, and human or other animal agencies; some plants and some animals act as catch-nets for rare and essential elements, and can be grown or included in any garden for that value alone. 2.7

In the third world, bags of superphosphate and nitrogen are hard to come by, even though Coca-Cola is cheap. It is here, especially in the tropics, that deep-rooted and mat-rooted perennials are essential to gardening.

Any system which pretends to be designed must take account of the synergistic nature of plants and animals, or to put it more simply, place plants and animals in the correct array in order to obtain a third benefit or interaction. Some specific examples are given below.

From the valuable summary of "plant defense guilds" (plants acting to protect plants) by Peter Atsatt and Dennis O'Dowd (*Science,* 193, 24-29, July, 1976) we have plants defined as interacting in the following three ways:

1 Some plants breed the predators that attack the pests on other plants. These act as insectaries or breeding grounds. Thus, *Phacelia,* planted in orchards, reduces the incidence of the *Prospatella* pest. Sorghum or lucerne interplants with cotton, and any umbellifera (dill, fennel) with brassicas (cabbage, cauliflower), strawberries in or near peach orchards, wild blackberry near grapes, and so on are instanced, often operating on a single pest species, but also, (as with fennel or dill) attracting or feeding predators that range over a garden eating many other insects.

Conversely, some plants (*Berberis*) carry over diseases of others, (rust on grain) and act as reservoirs of re-infection, and so are either contra-indicated, or used deliberately to suppress pest plants.

2 Plants repel browsers or pests by physical (spines) or chemical (phenols) methods. *Ranunculus* protects grasses from cattle, as the lactone ranunculin irritates the mucous tissue of herbivores. Similiary, *Trifolium fragiferum* (a cover) protects white clover from hares. Hard pressed Aboriginal gardeners can use *Haplopappus tenuirostris* to deter or even kill off feral donkeys and horses, and there are many lists of such poisonous weeds. Even feral goats are killed by browsing on rhododendron and azalea shoots.

These are then, the defenses of the hapless fellahin against the predaceous nomad flocks and the incursions of feral or uncontrolled stock into gardens. Olfactory "interference" is invoked to explain why brassicas grown with tomatoes are less attacked by pests, although the alternative explanation in *New Scientist* (Nov. '78) has intriguing possibilities, namely, plants scattered amongst others appear scattered to the pests, but (once pests breed on them) the "scattered" plants, surrounded as they are by other and insectary species, appear to the *predator* as concentrated food sources. At any rate (and computer studies aside) the dispersal of plants among other and varied species leads to far less pest infestation in all cases studied.

Shade cast by plants may protect insects or other plants from predator attack. Atsatt and O'Dowd instance the protection of Klamath weed from leaf-eating bettles, and (Peter Ebbsworth, in conversation) the shade cast on ponds by fringing trees protects mosquito larvae from those efficient predators, the notonectids or backswimmers. So, it can be seen that every factor can be used both for and against species survival.

3 Attractant or decoy plants may draw off pests from others, and even reduce the pest. So *Nepenthes* (catmint) has a fatal attraction to cats. A friend of mine once kept a Powerful Owl in a large-mesh cage. It ate the cats which came to kill it. Thus *Nepenthes* plus owls may prove a lethal combination for feral cats! Atsatt and O'Dowd record that *Solanum* (*S. nigrum,* etc.) grown with potatoes attracted egg masses of the Colorado beetle as a lethal

2.7 decoy. These attractants *plus* some mechanical trap device or trap-yards can remove or immobilize many animals or insects coming to plants. Wallaby in Tasmania are attracted to "wallaby wood (*Pittosporum bicolor*), and meat flies to the malodiferous *Arum decrunculus* or "dead donkey" lily. Gladiolus will trap and clear up onion rot, by preventing fungus sporulation.

It is of particular interest to note that alternate or interplanting of *non*-resistant and resistant plants prevent the build-up of pests, rather than the endless chase for more resistant varieties. I have grown spring and summer broad beans, not for food but to *attract* aphis, and hence their predators.

The end conclusion of the *Science* paper is of great interest, in that "a little powerful diversity" of the right kind is the key component of stability. And so we may ourselves design and strengthen the "plant defense guilds" which naturally exist, if we can define the ways in which these work, as above. So much for these interactions, but there are other strategies, some more direct, others less so, for instance:

- *Plants in obligate or beneficial root, or gaseous, contact.*

Apples and dandelions release the essential ethylene gas that causes pineapples and bananas to ripen, or ripening to occur. Quandong can germinate and establish only in root association with another plant. Marigolds prevent nematode attack on citrus roots, and so on.

- *Plants produce toxic or hostile conditions for other plants.*

Deep shade under *Coprosma* prevents weed establishment, phenols produced by bracken, walnuts, pine trees, act as growth inhibitors for other plants, and grasses secrete substances which kill young trees. All these factors can be used gainfully, or be nullified by design.

Then there are manurial or elemental factors to consider, especially in remote gardens:

- Species such as comfrey and coprosma provide potash for potatoes (as mulch or trenched leaves).
- Species such as tree lucerne or *Leucaena* provide the essential nitrogen as mulch, and smaller legumes provide nitrogen also, by root nodulation. (See also *Co-Evolution Quarterly,* Autumn, 1978 for such design work.)

Physical factors such as shelter, shade, reflection, or water usage interact plant to plant, with some plants being essential to others as windbreak, shade, host, or nurse species. Many 'rampant' plants nurse others to maturity.

The observant gardener can see for himself how plants benefit in association, while the mindless monoculturist tries to maintain simplicity at great cost to himself and his land.

Newman Turner[33] is the text for observant graziers—a man who observed his cattle. By deliberately including medicinal and vermifuge plants in pasture, he kept his stock healthy despite themselves, and there are now very good books on herbal medicines to guide the designer.

A number of books also exist which give suspect information, such as those which advocate garlic as a repellent to cabbage moth. As garlic is planted when the moth hibernates (in autumn), it may be said to have had a truly cosmic effect (the moth disappears when you plant garlic)—similar fairy stories are abroad.

However, many reasons for planting plants for other plants sake do exist, as I have tried to show in this section, and even if *devas* and fairies do operate, so do more mundane effects. Permaculturists can look on garden design as an intellectual exercise, with many more moves and infinitely more pieces than man or computer can deal with. Unhappily, many farmers are unsporting enough to out-poison rather than out-think their opponents (and customers) but good farmers are always good observers, and can strengthen the chance alliances they find at work, and allow weaker associations to wither if they will.

1 Animals

It is clearly impossible, outside of sterile laboratory situations, to exclude animals from agriculture. Whether they are termed pests, soil micro-organisms, domestic animals or wildlife

they will enter and be part of any system. Like plants, animals have suffered from the monoculture or mono-intellectual approach. Regarded as a source of meat, furs, hides or eggs only, they have been forced to a high-energy productivity, resulting in disease and low-quality or dangerous products contaminated with food additives, hormones and saturated fats. 2.7

The question, then, is—how should they be utilized? In permaculture we must try to use an element in all its energy functions, and the unique thing about animals is that they provide useful products from materials which are otherwise inaccessible to man. Thus animals can be used as:

- producers of meat, fibres, eggs, down, etc., grown from materials of little direct use to man;
- providers of high quality manures, again often from the wastes of man;
- pollinators of plants and as foragers, collecting dispersed materials from a permaculture;
- heat sources, radiating body heat for use in enclosed systems such as greenhouses and barns;
- gas producers (CO_2 and methane) again for use in enclosed systems such as greenhouses and digesters;
- tractors, which dig soils. Poultry, pigs and fish are efficient soil-turning, weeding and manuring machines for enclosed spaces or small allotments;
- draught animals (in all capacities) operating pumps and vehicles;
- pioneer bulldozers for clearing and manuring difficult areas prior to planting;
- as pest control mechanisms, devouring pupae and eggs of pests in fallen fruit, or in trees and shrubs;
- concentrators of specific nutrients useful to man, such as nitrogen and phosphates from flies and wasps;
- cleansing filters for water; and
- short grazers aiding in fire control.

To take advantage of these many functions we need only to design by controlling numbers and space.

All animal populations produce a surplus from natural increase, where they are managed as breeders. Like a crowded forest, too many animals on an area become non-productive, thus dense fish populations in lakes or rivers cannot put on growth and dense mammal or bird populations are self-thinned by starvation, crowding stress, or consequent disease and epidemic mortality.

Most selection pressures of this nature operate on young or very old animals, much as children and aged people in human populations are the first to suffer in famine or social disruption. This points up the fallacy of "minimum size" regulations in sedentary fisheries, where small fish are "thrown back" to grow. We should throw back the breeders and utilize the small fish. No farmer could survive if he killed breeding cattle, and no fishery will thrive under the same mismanagement.

If we do not cull animal species, nature will do so for us—mostly as catastrophic population crashes due to overcrowding. To exclude animals from agricultural areas is to kill them in the long term, and just as man himself is decomposed by bacteria and worms, so he can act as a decomposer in the matter of surplus animals.

So long as we manage animals, whether domestic or wild species, we can maintain healthy breeding populations. The emphasis in this book is on free range foraging, so that any animal is used in all its functions, not penned or restricted by energy-expensive means. There are, however religious or moral reasons not to kill animals, and ecological reasons not to rear them on expensive grain crops. The value of many animal species is that they can utilise foods (insects, windfalls, cellulose) not otherwise utilised by man, and their essential role in the tropics is to 'detour' the leaves of trees and monsoon grasses to nutrient—rich and available manures. Rank grasses may swamp man and gardens if not controlled by browsing species, and we can therefore see how religious proscription has (in its native climate) a sound ecological basis, in that cattle in monsoon areas are an essential adjunct to agriculture. Such restrictions do not, however, transplant well to every climate, and we should adopt a local morality.

Plants without animal foragers are like strawberries without cream, or men without women. In this sense, they too "hold up half the sky" and are always in beneficial interplay with plant

2.7 species. Just as we can assemble plant sequences, so we can assemble beneficial associations of animal species, and integrate plant with animal systems to mutual advantage. Thus, almost every statement we have made about plants can be made about animals, and to complicate matters we can use plant-animal structure interactions, some of which are outlined in section 8.

SOIL IMPROVEMENT 3

Bare soil is damaged soil and occurs only where man or introduced animals have interfered with the natural ecological balance. Once soil has been bared it is susceptible to further damage by the elements (sun, wind or water, or a combination of these) or invasion by flatweeds. Thus, the use of the conventional plough in cultivation not only damages soil life processes, but may cause more extensive soil losses. The three main approaches to minimal soil loss in agriculture are:

- growing forests and shrubberies to protect the soil;
- using ploughs that do not turn the soil; and
- encouraging life forms, especially worms, to aerate compacted soils.

All of these processes have the same result—soil aeration and safe nutrient addition. In order, they are termed re-afforestation, soil conditioning, and mulching or composting. The first two deal with large areas, the last with small areas. Forestry and soil conditioning produce their own mulch, while mulch can be applied to small gardens.

Often, the pest plants of which we complain (lantana, capeweed, blackberry, mullein, thistle and so on) are the attempts of damaged soil to produce a plant mat that will prepare the way for forest or crop. They are an indication that damage has occurred, that we have gone too far and have lost control of the land.

The initial step taken by the Chinese, setting out on their great work of desert reclamation, is to mat the dunes with willow and straw. The trees follow, weaving a mat of roots and leaves that stop water and wind erosion, and even (in the case of bamboo root 'rafts') moderate the effect of earthquakes on their dwellings.

BROADSCALE SOIL IMPROVEMENT 3·1

Both P. A. Yeomans and Geoff Wallace (of the Kiewa Valley) have evolved broadscale management of soils, to return them to productive and stable use. Neither have been knighted, made national heroes, nor even invited to take up chairs at leading universities concerned with the environment, but that is to be expected. Australia ignores her innovators and sends instead for overseas experts.

The importance of Keyline, and the tools developed by both Yeomans and Wallace, is that concreted, unproductive and sterile soil may be quickly rehabilitated. Using either Yeomans' "Bunyip Slipper Imp Shakaerator" or "Wallace's Soil Conditioner" or both, the result is that compacted soil is lifted gently (*not turned over* or reversed) aerated and loosened. Rain penetrates and is absorbed; soil temperatures rise, roots grow and die to make humus; weak carbonic acid from air, rain and roots dissolves nutrients from the ground, and the country comes to life again.

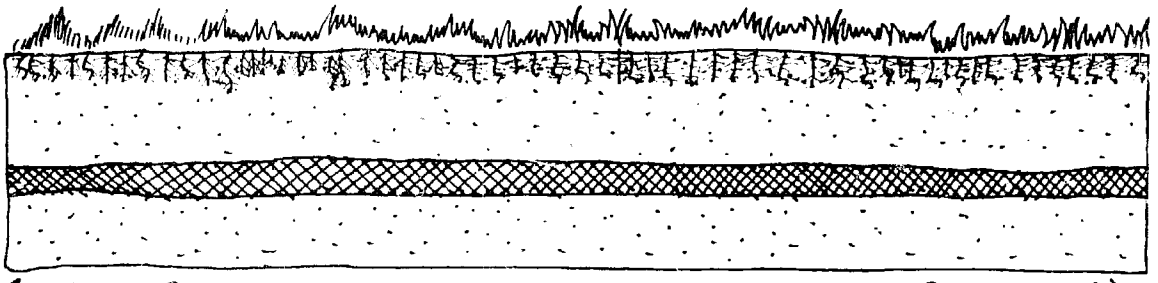
Apart from an initial top-dressing of phosphate or grossly deficient trace elements, no further top-dressing is used. When, after a few treatments, a black soil has redeveloped to 9" deep, trees and crops can be planted with assured success, and in the case of tree crops, the treatment gives permanent rehabilitation. I cannot think of a single political decision which is as important as the decision of such men to restore soil, for it is the products of the soil that allows politicians to survive, as Sir Albert Howard has so clearly demonstrated[21]. Such achievements should be available to the world, and their inventors set free as national teachers, to broadcast their skills where they are needed in the third world.

Both Wallace and Yeomans have shown that in a matter of two or three years, soils which take a century to evolve under forest can be recreated by man. Wallace has recorded temperature rises of up to 11 °C in soils under his reconditioned forest. Yeomans has shown how "water for every farm" (and clean water at that) is a result of Keyline. Clean water and healthy soil: these are the foundations of human and social health. Forget chlorination and the welfare state and go to the heart of the problem—the basic resources of a nation. Howard [21] has enough to say about the

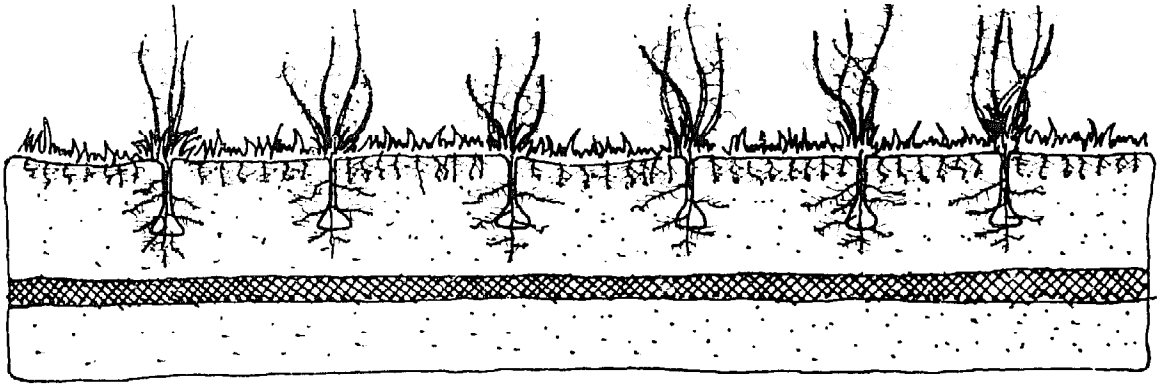
3.1 GRASS ROOTS

SOIL

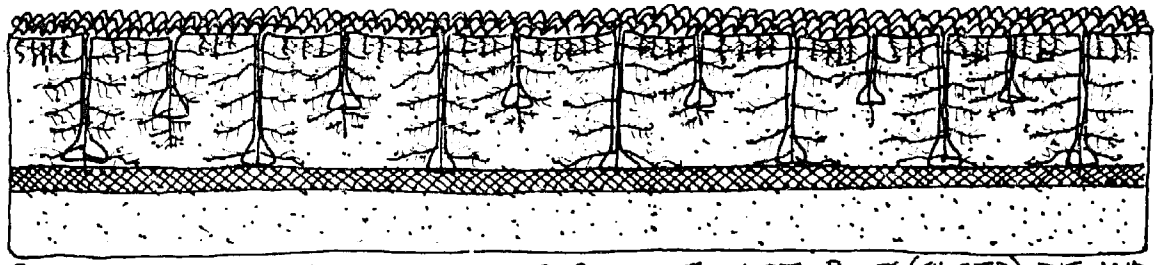
CLAYPAN (A)



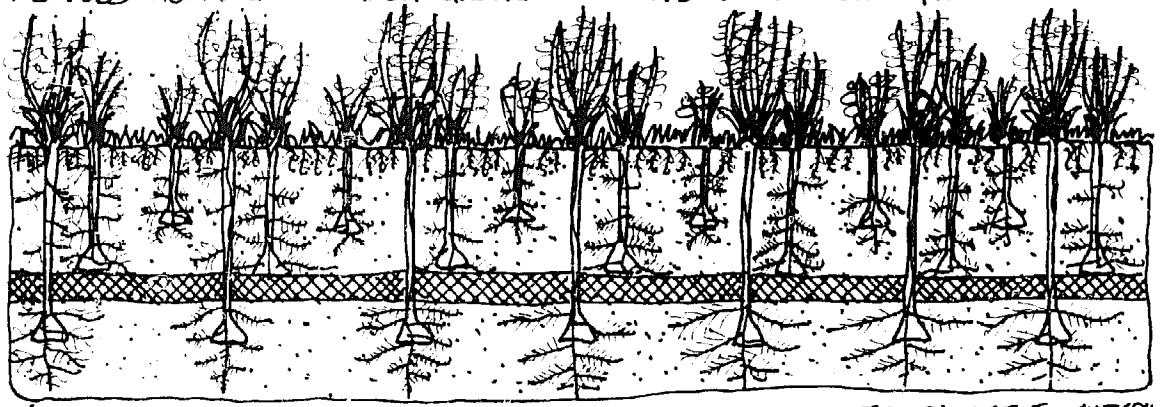
1 COMPACTED OR OVERGRAZED SOIL LACKS AIR, POSSIBLY HAS PLOUGH PAN (A) OF COMPACTED CLAY BELOW TOPSOIL. ROOTS WEAKLY DEVELOPED



2 FIRST RIP TO 75 OR 100 mm. ROOTS FOLLOW DOWN TO AERATED SECTION. WATER ABSORBS THERE INSTEAD OF RUNNING OFF



3 NOW, NEW GROWTH IS CLOSE-MOWN OR GRAZED OFF SHORT. ROOTS (SHOCKED) DIE AND SOON AFTER SOIL IS RIPPED TO 150~225 mm AND NEXT GROWTH CYCLE BEGINS. SOIL SOMEWHAT CRACKED BY CHISEL PLOUGH, AND DEAD ROOTS FORM ORGANIC MULCH, AS DOES MOWN GRASS ABOVE GROUND. THE SECOND GROWTH IS MOWN, SECOND ROOT SETS DIE.



4 THIRD RIP TO 500 mm BREAKS UP PLOUGH PAN AND ALLOWS FREE DRAINAGE TO SUBSOIL. DEAD ROOTS FORM ABSORBENT MATS, SOIL TEMPERATURES ARE MORE EVEN, MULCH ABOVE GROUND ALSO HELPS. WORMS MOVE IN TO EAT DECAYED MATERIAL, AND FURTHER AERATE SOIL, CARBONIC ACID AND HUMIC ACIDS RELEASE SOIL NUTRIENTS.

FIG. 3·1: SOIL REHABILITATION BY CHISEL PLOUGH.

disastrous results of agricultural education which is confined to the laboratory, or university and ignores whole systems and field trials. 3.1

Delinquency is part of mindless damage, and this is precisely what has happened to the lanscapes of the man behind the plough. Damaged landscape confronts us everywhere, that the greatest delinquency occurs in the poorer nations is no accident—after poverty follows extinction, the desert, salt, and silence.

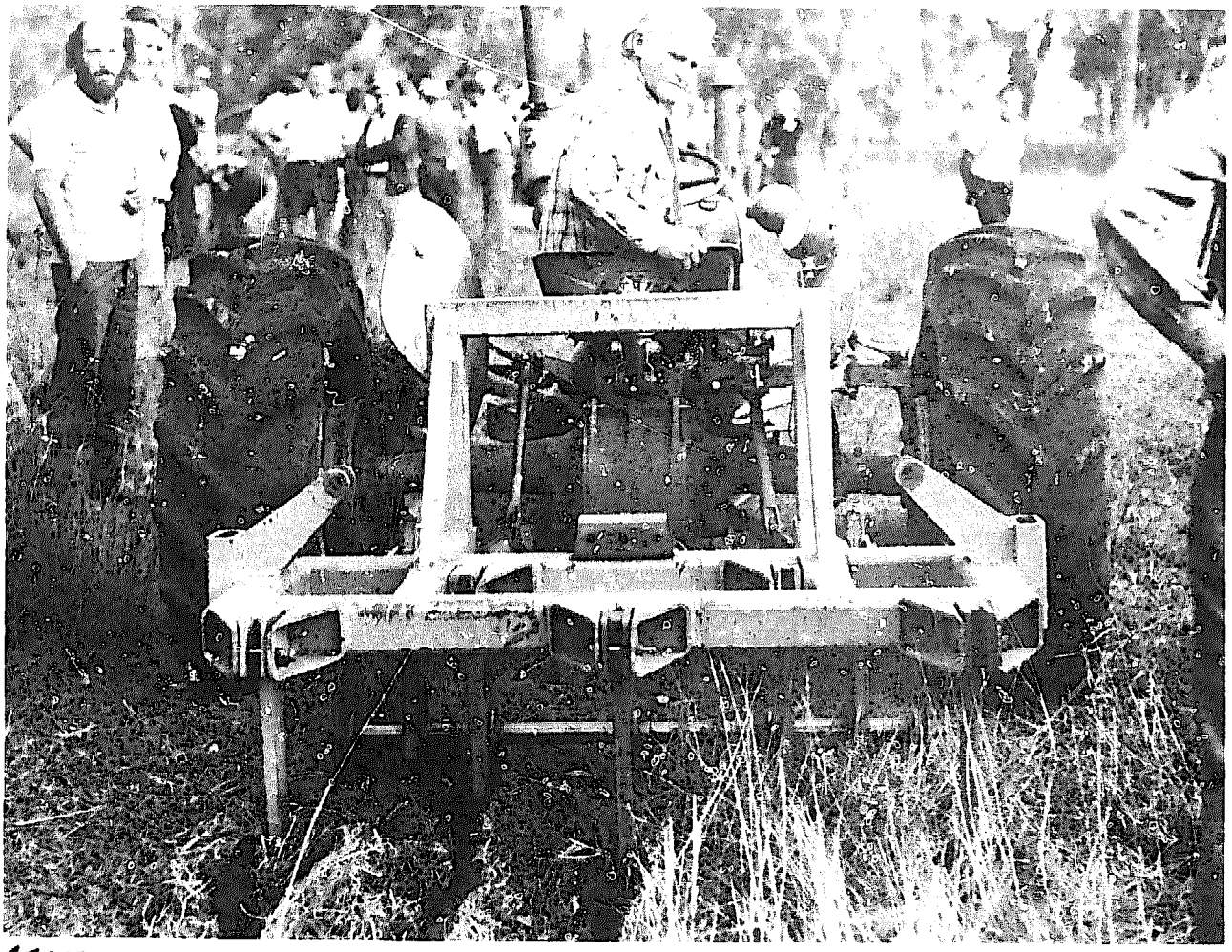
If nations would set a goal for soil health, the other situations which plague us would resolve themselves, and a sustainable philosophy would develop. I mention broadscale techniques because uninformed people think that organic or rehabilitative methods can be applied only to small-scale projects. Given men like those mentioned, we could rehabilitate a nation.

What Yeomans and others achieve with the chisel plough and no-tillage mechanization, Fukuoka[1] does with deep-rooted plants such as the Japanese radish and lucerne, but his system has not been compacted by heavy machinery or domestic stock. Even strong roots cannot often break up hard pans, and the vibrating action of the shakaerater is needed for this extreme of rehabilitation.

Once the soil is on the way back to health, it is time to plant tree and field crops. A summer spent on bringing the soil to life is not a summer wasted, for trees respond more vigorously to the new soil conditions, and make up for lost time in a single season: an olive or carob struggling to survive in the original condition of compacted soil makes 90 cm - 1.2 m growth in improved soil, and may well bear in three or four years instead of 17-18 years or more.

To summarise briefly, the results of soil rehabilitation are as follows:

- living soil: earth worms add alkaline manure and act as living plungers, sucking down air and hence nitrogen;



GEOFF WALLACE DEMONSTRATES HIS SOIL CONDITIONER AT KIEWA.

3.1

- friable and open soil through which water penetrates easily as weak carbonic and humic acid, freeing soil elements for plants, and buffering pH changes;
- aerated soil, which stays warmer in winter and cooler in summer;
- the absorbent soil itself is a great water-retaining blanket, preventing run-off and rapid evaporation to the air. Plant material soaks up night moisture for later use;
- dead roots as plant and animal food, making more air spaces and tunnels in the soil, and fixing nitrogen as part of their decomposition cycle;
- easy root penetration of new plantings, whether these are annual or perennial crops; and
- a permanent change in the soil, if it is not again trodden, roiled, pounded, ploughed or chemicalized into lifelessness.

Trees, of course, act as long-term or inbuilt nutrient pumps, laying down their minerals as leaves and bark on the soil, where fungi and soil crustacea make the leaves into mulch.

Wallace has produced a soil conditioner of great effectiveness. A circular coulter slits the ground, which must be neither too dry nor too wet, and the slit is followed by a steel shoe which opens the ground up to form an air pocket without turning the soil over. (See Plates 1 and 2.) Seed can be dropped in thin furrows, and beans or corn seeded in this way grow through the grass to make a bumper harvest. No fertilizer or trop-dressing is needed, only the beneficial effect of entrapped air beneath the earth, and the follow-up work of soil life and plant roots on the re-opened soil.

Graphic illustration of the effects of such measures on soil temperatures occur on frosty nights. Aerated soils are frost free while compacted soils are easily frosted. Wallace clearly demonstrates this effect by growing 'tropical' crops in his Kiewa Valley farm, only 40 miles from the snowline in winter.

PLATE 3.2 : DETAIL OF WALLACE SOIL CONDITIONER. COULTER SLITS SOIL, HAFTED 'SHOES' FOLLOW, TO MAKE AIR TUNNELS BELOW SOD.

There is only one rule in the pattern of this sort of 'ploughing' and that is to drive your tractor or team slightly downhill, making herring-bones of the land: the spines are the valleys and the ribs slope out and down-slope. As Geoff says: "Even a child can keep a machine travelling slightly downhill." The soil channels, many hundreds of them, thus become the easiest way for water to move, and it moves *out* from the valleys and below the surface of the soil. Because the surface is little disturbed, roots hold against erosion even after fresh 'ploughing', water soaks in and life processes are speeded up. A profile of soil conditioned by this process is illustrated in Fig. 3.1. 3.1

Wallace sees no point in going more than 100 mm in first treatment, and to 150-225 mm in subsequent treatments. The roots of plants, nourished by warmth and air, will then penetrate to 30 cm or 50 cm in pasture, more in forests. For disposal of massive sewage waste-water, Yeomans recommends ripping to 90 cm or 1.5 m, and a trial of this system is being made at Maryborough (Vic.) below sewage lagoons.

I have scarcely seen a property that would not benefit by soil conditioning as a first step before any further design input. Only very stony or sandy soils cannot be effectively treated (here soil treatment is mainly by biological means) but it can in fact be used on football ovals to prevent soggy compaction without seriously interfering with usage. In the same way, pasture and crop do not go out of production as they do under bare earth ploughing with conventional tools, and the life processes suffer very little interruption.

For small gardens of compacted earth, Yeomans recommends driving in a heavy fork and gently levering the soil until it cracks open.

NO-TILLAGE CROPPING 3.2

Until I read Fukuoka[3], there was no satisfactory basis, to my mind, for including grain and legume crops in permaculture, but the system outlined in *The One-Straw Revolution* (Rodale, 1975), seems to have solved the problems of no-dig grain cultivation. Both P. A. Yeomans and David King of Nimbin also recommend the work of G. F. Van der Muelen, a tropical agronomist who has published *The Ecological Methods for Permanent Land Use in the Tropics,* available from Ranonnkelstraat 119, The Hague, Netherlands. Van der Muelen uses, for example, the lab-lab bean (*Dolichos lab-lab*) under *Borassus* palm as a perennial system; a friend of Yeomans uses lab-lab with barley to great effect in annual grain culture.

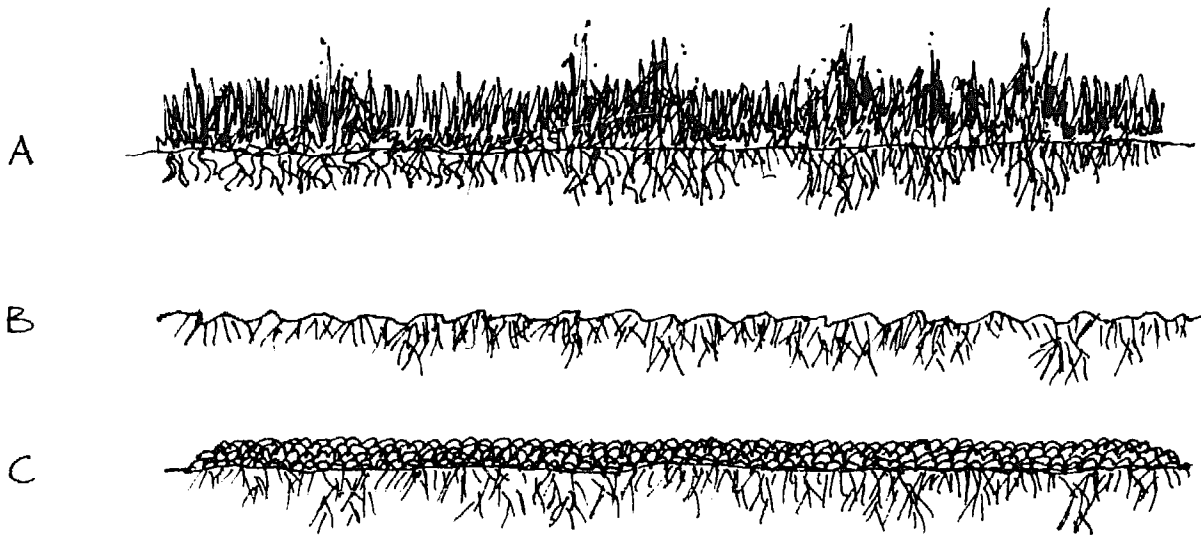
In brief, the system combines the usual rotation of legume/grain/root crop/pasture/fallow/legume into a single grain/legume mixed crop. There is every reason to do the same for tree-crop systems, including leguminous trees (wattle, black locust, tree lucerne) in any orchard, nut-crop or timber-crop situation. Any smallholder can, without tractor or machinery, produce a heavy crop of grains and legumes if "simultaneous rotation" is practised. The method is very well suited to sewage or sullage disposal from holding lagoons, where no poultry manure would be needed.

In this treatment I have combined data from three books (Refs. 3, 12, 13) using Fukuoka's methodology, and data from the latter two references (12, 13) to evolve a no-dig and permanent grain-crop system that fits into the permaculture system. Grain crops are an important food source, and are available within a season. Most areas suit grains, and legumes are the essential plants to fix nitrogen for the grain crop. A grain/legume diet gives a complete protein supplement (*see Diet for a Small Planet,* Frances Moore Lappé, FOE/Ballantyne).

The principles of continuous mulch (with clover) plus double-cropping using winter and spring sown grains is what makes it possible to use small areas (400 m^2 or less) to support a family of five on grain. If paddy rice is to be grown, the area must first be graded or levelled, and a low bund (water-wall) built around the plot, so that 50 mm or so of water can lie on the ground in December (see Ref. 12 for technique of sealing bund walls with plastic).

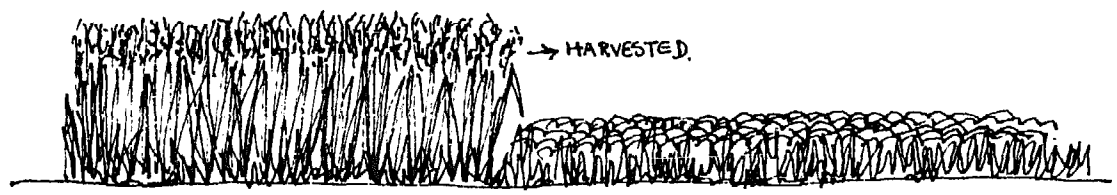
After levelling or preparation in summer, the area has lime or dolomite spread over it, watered in, and made ready for autumn planting. To start the continuous crop system off, a complete (seed-free) mulch cover of straw, seagrass, shredded paper or sawdust etc. is applied at about 900

3.2



1 AUTUMN: ORIGINAL SURFACE IS MOWN (A), PLOUGHED (B), AND MULCHED (C) ESSENTIAL MANURES ARE ADDED, AND RICE, RYE, AND WHITE CLOVER BROADCAST SOWN. CLOVER INNOCULATED.

2. WINTER: CLOVER AND RYE SPROUT AND GROW, RICE LIES DORMANT IN HUSKS.



3 SPRING/SUMMER: RYE RIPENS AND IS HARVESTED. RICE SPROUTS AND GROWS. RYE STRAW IS RETURNED TO FIELD. LATER RICE IS KEPT SATURATED AND IS HARVESTED. RICE STRAW IS RETURNED.

4 AUTUMN: COMMENCE CYCLE AGAIN AS AT 1C, VARY CROP TO MILLET, WHEAT, BEANS, LENTILS, ETC.

FIG·3·2: SCHEMATIC OF NO-TILLAGE GRAIN AND PULSE CROPPING

kg/1000 m² (8000 lb/acre). If no mulch is available, seed can be covered as usual, by raking in. I will deal with more than one plot here, to show how different plants can be treated. In April, seed is broadcast below the mulch as follows: 3.2

Plot No.	1	2	3	4	5
Seed	Rice White clover Rye	Rice White clover Barley	Rice White clover Millet	Rice White clover Winter wheat	Rice White clover Oates

Rice lies until spring, and other crops germinate soon after sowing. Assuming that the rotation has been proceeding for one year, and that crop straw is now available for mulch on site, the year then proceeds as follows:

April: A thin layer of chicken manure is broadcast over the area. Use clover at 1 kg per ha. (1 lb/acre), rye and other grains at 7-16 kg per ha, and rice at 6-11 kg per ha (5-10 lbs/acre). (Use inoculated clover if this is the first crop.) Seed can be scattered first, then straw-covered, thus protecting it from birds. In the second year, rye and clover are sown into the ripe rice crop at this time. The rye and other grains are sown mid-month.

May: First week—last year's rice is reaped, the crop dried on racks for 2-3 weeks, and threshed. All rice straw and husks are returned to the field. Unhusked rice is now resown within a month of harvesting, just before the straw is returned.

June-September: Migrate to a sunny climate, or admire the winter crop. Light grazing of the winter crops by sheep or geese assist the stooling of plants and will add manure. Check and sow any 'thin' areas as soon as possible. When the crop has reached 150 mm or thereabouts, about 100 ducks per ha (40/acre) will reduce pests and add manure. Fields (or paddies) are kept well-drained.

October: Check that rice is growing, and re-sow thin patches if necessary.

November: Rye, barley etc. is harvested in the middle of this month, and stacked to dry for 7-10 days. The rice is trodden, but recovers. When other grains are threshed, all straw and husks are returned to the fields, moving each straw type on to a different plot thus:

Plot No.	1	2	3	4	5
Straw	Oats	Rye	Barley	Millet	Wheat

December: only rice remains. Summer weeds may sprout; these are weakened by flooding for 7-10 days, until the clover is yellow but not dead. Rice grows on until May harvest.

January-March: the field is kept at 50-80% saturation under rice, while seeds of other grains are prepared for sowing in April. The cycle then continues as before, but now using the crop straw for mulch. Each person must evolve their own techniques and species mixtures, but once a cycle is perfected there is no further cultivation, and straw mulch is the only weed control: it helps if the area of bunds around the crop is planted to *Coprosma,* comfrey, citrus, mulberry, lemon-grass, tree lucerne, pampas, or other weed-controlling shelter plant. Mulch with sawdust under these borders to prevent weed re-invasion from the bunds or surrounding land.

Where a paddy is not possible, dry-land rice or other grain species can be used, and spray irrigation replaces summer flooding. In monsoon areas, summer rain should suffice. For amateurs, seed should be sown at the higher rates until skill in even broadcasting is achieved. Mechanical spinners can be used for larger areas. Where rice cannot be grown (e.g. very cool areas) other grains may be substituted and short-term cycles may be invented. (Spring wheat or corn sown in Sept-November, for example, with oats, barley or wheat as winter crop.) Other legumes can also be tried.

Logsdon[12] gives sources for seed and small machinery and data on home processing for threshing, husking and grinding. (The CSIRO "Ripple-Flo" machine, now made in Australia,

3.2 carries out all these processes plus the chaffing of grain stalks.) In humid climates, grain should be dried to 14% moisture before storage in pest-proof barrels or drums. In clean-tilled ground the amount of seed needed is 4-5 times as much as in this straw-mulch method. Fukuoka's book gives much more data on no-tillage gardening for vegetables and fruit, and for the tree crops he used 12 wattle trees (silver wattle for example) to the hectare (5/acre) instead of clover. Fukuoka[3] has maintained this no-dig cycle for 25 years, and his soil is improving, with no fertilizer other than chicken and duck manure, no sprays, and no herbicides.

Where sparrows are a problem, the grains are mixed with mud, pressed through wire-mesh and rolled into small balls, or dampened and shaken in a tray of clay dust to form mud-coated pellets. Pellets can also be formed by extruding mud and grain through a domestic mincer, on to a vibrating table of dust or flour.

1 Grain Crops

Rice (Oryza sativa), although a short-day cereal suited to latitudes to 40° N. and S., would be possible or even a probable success in cool climates. It is self-pollinating. The U.N. notes that rice responds to nitrogen (Fukuoka's chicken manure). The Japanese control disease in seeds by soaking in 40% formalin diluted 50 times with water. The margins around the paddy-fields should be mown or planted with shrubs or tall perennials to reduce weed invasion. Wild grasses act as reservoirs for disease. Again, Fukuoka scythes wild grasses and ignores sprays and insecticides.

Seed at about 13% moisture is stored in a cool place. "Good yields may reach 3,000-4,000 kg/ha., or about 3,500 lbs/acre".[13] 88 bushels = 5,200 lbs (sometimes 116 bushels) plus 9000 kg of straw per hectare (8000 lbs/acre)[3]. (These differences in yield illustrate how much more efficient is the straw-mulch system.)

Rye (Secale cereale): a long-day plant suited to cool areas; usually winter-grown but some spring types are available. Ripens in about 37-71 days. Pollination is by wind: autumn-planted (April-June) at 55-60 kg in irrigated ground. Some nitrogen is needed on poor soils. Requires good moisture (one irrigation) at flowering. Ergot is removed in a 20% solution of common salt, seed is then rinsed and drained leaving germination unaffected. Crop must be threshed within a few days of ripening, and plants cut at the "wax-ripe" stage, otherwise spikes dry out and seed starts to shatter when husked. Store below 14% moisture. Good yields reach 2,800 kg/ha., about 2,400 lbs/acre[13], 5700 kg/ha (5200 lb/acre or 88 bushells).[3]

Wheat (Triticum aestivum): a long-day plant for cool areas. Some varieties are grown in Alaska. There are both winter and spring wheats. Needs a sunny period of 6-8 weeks for ripening. Well-drained and heavy soils are best. Self-pollinating. Species will not cross-pollinate over hedge barriers. Sown at 40-80 kg/ha (36-72 lb/acre). Responds to nitrogen. In dry areas, flood irrigation is useful, but this should cease when grain is filled. Cut when seed is doughy and fingernail will still dent seed. Dry in field, thresh, and store below 21%-14% moisture. Good yield is 1100 kg/ha (1000 lbs/acre)[13].

Barley (Hordeum vulgare): a long-day plant for cool areas; sub-tropical to arctic. Spring types mature in 60-70 days, winter types in 160 days. Self-pollinated. Sown at 70-120 kg/ha. (64-108 lbs/acre) under irrigation in Autumn, or at 13 kg/ha (12 lbs/acre) in mulch[3]. Control ergot as for rye. Has less pests than wheat. Grain must be hard before threshing, straw dry. Store at 14% moisture in cool dry conditions. Good yield is 3000-3500 kg/ha (3300-3850 lbs/acre)[13]; 4700 kg/ha (5200 lbs/acre), or 22 bushels[3].

Buckwheat (Fagopyrum Sp.) F. esculentium, F. tartaricum, F. emarginatum: suits a wide range of climates. *F. esculentium* is best for cool moist climate. Wide range of soils, even infertile and poorly-tilled or acid soil. Pollinated by insects, needs (and is liked by) bees, at 2 hives per ha. Frost tender. Sow only after all frost danger is past at 25-40 kg/ha (22-36 lb/acre); not more, or less seed is produced. Lime may help. Few diseases. Normally harvested at 10 weeks, when seed at *base* is fully ripe. Threshes easily. Seed may be dried on floor. Good yields 4200-4400 kg/ha, (3800-4000 lb/acre)[13]. An excellent green manure for poor soils.

Oats (Avena sativa, A. byzantina): long-day crop of winter and spring varieties, best in cool climate. *A. sativa* best winter crop in cool areas. Neutral soils of many types (dry loam best). Self-pollinated. Lodges (falls) with high nitrogen, so needs less of this than other grains. Sow at 50-200 kg/ha (45-180 lb/acre) in Sept.-Oct. for Feb.-March harvest, or in autumn for winter vatieties. Water needed at flowering. Harvest when straw still a little green, grain at hard dough stage. Store below 14% moisture. Good yields at 3000 kg/ha (2700 lb/acre)[13]. 3.2

Quinoa (Chenopodium quinoa or Canihua, *C. pallidicauda*): Grown in S. America at high altitudes (Peru, Argentina), *C.quinoa* ripens in 135-145 days, Canihua in 165-172 days. Tolerant of soils and salts. Spring-sown at 10-15 kg/ha (9-13½ lb/acre). Birds a problem. Plants are pulled when seed resists finger pressure. Pile in stacks to dry. Good varieties (1000 varieties available), yield 2000-3000 kg/ha (1800-2700 lb/acre)[13].

Teff (Eragrostis teff): neutral daylength. White-seeded types suited to summer-dry season, brown-seeded to summer-wet seasons. Drought-resistant, but needs shelter when flowering; suits a wide range of well-drained soils; grows well on sandy soils. Self-pollinating. Sow in spring for Autumn harvest at 10-12 kg/ha (9-11 lb/acre). Thin if necessary. Harvest when green panicles turn grey. Yields 2000 kg/ha (1800 lb/acre)[13].

Millet (red millet, white millet, broom corn): treat as for maize (below), planting soaked seed 10 days later than maize at 9 kg/ha (8 lb/acre)[12]. All varieties grow quickly and need little water. A good crop to use where other grains have missed in earlier plantings. Cross-or self-pollinating. Harvest when seeds are ripe: hang heads in barn, these can be fed directly to poultry, like sunflower heads. Seed stores well. Birds are a problem with millet crops; poultry appreciate seeds.

Maize or sweet corn, popcorn (Zea mays): a short-day plant, yet suited to 40°S. or N. and sub-tropics. Stands slight frost only. Varieties seed from 50-130 days. Prefers well-drained, neutral soils. Cross-pollinated by wind, so needs tall windbreaks to keep varieties pure. Often followed by wheat or barley, rotated with peas, peanuts, soya beans. Sow Nov.-Jan. "When oak leaves are as big as squirrel' ears, or soil temp. is 60°"[12], at 15-30 kg/ha (13½/27 lb/acre). Thin if necessary, to 1200-1400 plants/ha (490-560 plants/acre). Needs less nitrogen, more phosphate and potash than other grains. Irrigation at dry periods increases seed yield. Sweet corn harvested at 'milky' stage and frozen, or seed cobs allowed to dry on plant. Can be stooked in fields, husked and fed on cob to poultry, pigs, or the seed may be stripped off and stored. Yields 1200-1500 kg/ha (1100-1350 lb/acre). It is also possible to graze off the lower leaves with lambs, and then turn pigs into the field to harvest cobs. Cattle and poultry will scavenge remains, if any, but then few stalks are left to mulch, and straw must be 'borrowed' from elsewhere. A good interplant for this grain is climbing beans (twine on corn stalks), or broad beans. Melons or pumpkins can be produced at ground level in sunny areas.

Pulses and Legumes, Hedgerow and Oil Plants 2

Broad beans (Vicia fabia): long-day, cool climate plant. Frost hard. Lime heavy loams, drain well. Bees help seed set, but self-pollinated. Sow Apr.-Jun. at 200 kg/ha (180 lb/acre) (35-40 plants/m²). Some manure important for phosphorous, or rock phosphate. Cut before top pods ripen, stack to dry. Yields 1500 kg/ha (1350 lb/acre). As well as seed, tops can be used as a green vegetable,[13] and young top pods eaten green as they form. If stems are hard-cut after harvest, they resprout the following autumn.

Vetch (Vicia spp., especially *V. ervilia):* long-day cool climate pulse, grows on dunes, wet soils. *V. pannonica* best for heavy soils, *V. ervilia* for cold resistance. Produce more seed on less fertile soils. Self-pollinating, but helped by bees. Often followed by maize, wheat, or can be mixed with barley, oats, rye, or wheat. Sow Feb.-Apr. or as a winter crop at 40-50 kg/ha (36-45 lb/acre), or 20 kg/ha (18 lb/acre) with 40 kg (36 lb) of grain oats, 80 kg (72 lb) of rye. Best sown with oats, as seeds mature together. Not usually irrigated. Cut when *lower* pods ripe. *Ervilia* is the later ripening variety. Oat and barley seeds readily separate from vetch. Store dry. Yield to 1000 kg/ha (900 lb/acre) on heavy land (*V. ervilia*)[13].

3.2 *Lentils (Lens culinaris):* a long-day plant for mediterannean climates, or as a winter crop in tropics. Very hardy to frost. Self-pollinating. Often sown with barley, in rows 2 m wide, alternating. Does not need much nitrogen; has few pests. Sow at 30-80 kg/ha (27-72 lb/acre)[13], ripens in 90-150 days. Harvest when lower pods brown; bundles pulled and dried over several days. Flailed or threshed if with grains. Av. yield 600-1000 kg/ha (540-900 lb/acre)[13]. Sow in June-Aug. or Nov.-Aug. in med. climate.

Chick-pea (Civer arietinum): a day-neutral plant requiring cool weather for best growth. Can stand low temperatures. Matures 90-100 days. Needs well-drained soils. Self-pollinating. Usually follows wheat, rice, oats. Sow in Sept.-Nov. as a spring crop at about 40-60 kg/ha (36-54 lb/acre). Often irrigated in dry periods. Harvest when seed well-developed but green, leaves reddish-brown. Pull or cut, stack 1-2 weeks in field. Flail; yields 900 kg/ha (810 lb/acre) under irrigation[13].

Field pea (Pisum sativum): long-day plant of cool moist climates. More damaged by high temperatures than by frost. Self-pollinating. Often precedes wheat. Sown Aug.-Nov. at 100-150 kg/ha (90-135 lb/acre). Potash useful in wet climates. Water at blossoming, and again just before pods form, or at half-full if no rain. Harvest by pulling or cutting when peas split without moisture released. Stack 10-15 days, dry to 15% moisture. Yield about 1000 kg/ha (900 lb/acre)[13].

Lupins (Lupinis spp.): long-day or green crop preferring cool climates, grown as summer or winter annuals, maturing seed (if needed) in 100-150 days. Prefer neutral light soils. Bees are main pollinators. Often grown after peanuts, before grains, or even useful to pioneer land (if inoculated). Sow Sept.-Nov. or Mar.-May at 40-80 kg/ha (36-72 lb/acre). If used as a pioneer, add phosphates. Rabbits a nuisance. Plants cut (if for seed) when pods ¾ brown, bunched and threshed over wire frame. Average seed yield 800-1000 kg/ha (720-900 lb/acre)[13]. A new lupinis-free variety of the perennial Russel Lupin is being developed in the U.K. as a human and stock food—a sort of perennial pea.

HEDGEROW AROUND FIELDS

Tree Lucerne (Chaemocytisus proliferus): a small tree to 4 m. Hardy, perennial legume. Early-flowering, June-Jan. at Lat. 40°S. Seeds Jan-Mar. Abundant seed for poultry forage, foliage as cattle or sheep forage crop. Wide range of soils, clay, clay-loam. Pollinated by insects, mainly bees. Sown early summer, pods for seed as for lupins (above). Stands pruning for bundles of seed-pods. Useful hedge plant for wind protection or with *Coprosma* seed as poultry fodder. Used also in double-fenced strips as summer cattle and sheep fodder. Prunings used for mulch. Several other hedgerow plants are mentioned elsewhere in this book. (See section 4.4.)

OIL PLANTS

A cycle that could be tried on sandy soils is peanut/potato, intercropped with lupins as green manure. Mulch the area with straw or seaweed over hills and shelter by using Russell lupin (perennial) as a windbreak.

Peanuts: hand-shelled from raw seed, are planted and can be inoculated if no clover present. Plant after last killing frost Oct.-Dec. at 33 kg/ha (30 lb/acre), rows 90 cm, seed spaced at 39 cm on ridges (24,600 plants per hectare or 10,000/acre give max. yield). Weeds must be controlled by mulch, or peanuts are difficult to harvest. Chicken manure as *thin* scatter helps crop. If rain poor, irrigate every 10 days after flowering. Plants are lifted when leaves yellow and some pods are brown on inside surface (about 120–140 days). Need ploughing on heavier soils, can be pulled in sandy soils, dried and stripped (oil and seed crop).

Modifications to the above systems must be worked out locally, preferably on a small scale (mowing weeds instead of flooding paddies, for example).

Further helpful data is given in Phillips, S. H. and Young, H. M.[4]. This book, although oriented to heavy machinery and sprays, gives some useful hints for no-tillage farmers. For exam-

ple, rye and wheat are broadcast into soybean crops when the leaves on the latter begin to fall—the falling leaves hide the seed from birds. Soybeans (or other legumes) are broadcast into the stubble of oats, barley, wheat, or rye, as is lespedeza, which is autumn-harvested. Peas are planted after corn, and green peas are followed by corn. Other crops suited to no-tillage are cucumber, watermelon, tomato, cotton, tobacco, sugar beet, pepper, vetch, sunflower.

Soybeans following grain are planted the last week of May or up to 3 weeks later in straw mulch.

The rather mind-boggling problem is to work out useful permutations on the method. If we have, say, 8 grains, 3 of which are winter/spring forms, 6 legumes (all with different bearing) and seasons of either winter or summer rain, then the possibilities are intricate. Other complications are dryland, spray-irrigated and paddy-field systems. And, in the case of any but paddy crops, the potential for integration with perennial or tree crop systems. It remains to run trials. One limitation is that "spring" straw cannot be strewn over the seed of the same crop (and so transmit disease), whereas straw put on in autumn or mid-summer rots before the spring crop shoots.

There are, then, a confusing number of possibilities to try, and the best way to proceed is to map the sequences on paper for a number of small garden plots, try these for your area, and only proceed to broadscale trials when the trial sequences have proved successful. There is, however, no doubt in my mind that we can evolve several permanent no-tillage rotations with modest trials. What we omit here is the 2-4D or paraquat sprays which are the basis for no-tillage where the high-energy, low know-how and agribusiness operators use it. Fukuoka[3] controls weeds and pests by natural means (frogs, spiders, straw, flooding or cutting).

Labour in the system is minimal, and we hope that many people will run trials on a backyard basis, with chick peas, lentils, beans or lupins as alternative legumes. Feedback on results would be much appreciated, and successful trials will be published in the Permaculture Quarterly.

Why reference three books on grain crops? The comparisons alone are interesting. The FAO bulletin and Phillips and Young[4] could be characterised as "consciously inorganic", Logsden as "consciously organic" and Fukuoka as "non-consciously organic". I think that the sequence is one of evolution in approach and process: the yields increase as the understanding increases, and that about sums it up. Fukuoka has "stacked" crop rotation by sowing into the preceding crop, and using white clover as a permanent base. Logsden has rotation well worked out, but separated in time. The FAO has some ideas of rotation, but no system is offered. Just as Fukuoka stacks his grain/legume system, so he stacks his citrus/wattle system. It is in this collapsing of the time for successions that he shows sophistication—order in time by apparent disorder in space. So it is with all truly creative syntheses.

Distribution of Yield 3

The concentration of yields into one short period is a fiscal, not an environmental strategy, and has resulted in a "feast and famine" regime in market and fields, with consequent high storage costs. Our aim should be to disperse yield over time, so that many products are available at any season. This aim is achieved, in permaculture, in a variety of ways:

- by selection of early, mid and late season varieties;
- by planting the same variety in early or late-ripening situations;
- by selection of long-yielding species;
- by a general increase in diversity in the system, so that leaf, fruit, seed and root are all product yields;
- by using self-storing species such as tubers, hard seeds, nuts or rhizomes which can be dug on demand;
- by techniques such as preserving, drying, pitting, and cool storage; and
- by regional trade between communities, or by purchasing land at different altitudes or latitudes.

3·3 SHEET MULCH FOR HOME GARDENS

Although there was a description of sheet mulch for gardens in *Permaculture One* (p. 93[1]), this technique has brought up many questions which I hope this account will answer. The technique is figured in Fig. 3.3, and similar methods are described by Ruth Stout[8] together with others, published and unpublished, all of whom have their variations. Video film of the author demonstrating the process is available from WAIT (West Australia Inst. of Tech., Perth): contact Barry Oldfield, or *via* Smith's Bookstore, Canberra, contact Harry Smith.

Now, the first thing to say about sheet mulching is that it saves a great deal of labour, and a great deal of water, while dispensing with material that normally goes into landfill. Thus mulching also saves money for public authorities, and produces an excellent soil. Another appeal is that the system is tool-free and suppresses *all* weeds: ivy, onion and spear twitch, kikuyu and buffalo grass, docks, dandelions, oxalis, onion-weed and even blackberries. Before starting, plant any large trees or shrubs from the nursery as usual.

The first step (Fig. 3.3) is to sprinkle the area with a handful of dolomite and a handful of chicken manure or blood and bone; the latter two add nitrogen to start the process of reducing the carbon in the following layers. Don't bother to dig, level, or weed the area. Your first attempt should be very close to the house, preferably starting from a foundation or path which is itself weed-free. Thus, you are protected from invasion of weeds from the rear, so to speak.

Now, proceed to tile and overlap the area with sheet mulch material. This can be cardboard, wallboard, newspaper, old carpet, underfelt, old matresses or clothing, rotted palings or thin wood. If you have a garbage pail of non-noxious wastes like tea-leaves, peelings, leaves and small food scraps, scatter these first, for the worms. If you have a source of weed-seedy hay or like material, bury this also *below* the overlapped material, so that no weeds follow on. Cover the area to be mulched *completely* leaving no holes for weeds to poke through. If you have a valuable tree or shrub in the way, tear paper half across and pull it around the stem. Serve another, at right-angles to the first. Go on, leaving only valuable plants (some dandelions, clover, useful small plants) with their leaves poking out. Water this first layer well, and then apply, in sequence:

75 mm of either

- horse-stable straw
- poultry manure in sawdust
- seagrass or seaweed
- leaf mould or raked leaves

or any of these mixed.

All of these are manurial, or contain essential elements. All hold water well. Follow these with dry, weed-seed-free material on top:

150 mm of either

- pine needles
- casuarina needles
- rice husks
- nut shells
- seagrass (*Zostera*)
- leaf mould or raked leaves
- cocoa beans
- dry straw (*not* hay)
- bark, chips, or sawdust

or any of these mixed.

FINISH. Water until fairly well soaked. Always put at least 225 mm of cover over the paper, cardboard etc. 300 mm is better, 375 mm too much, less is of no use, so do a small area very well, not a large area thinly or sloppily. It takes about 20 minutes to cover an area some $10m^2$, and if you have all the materials at hand it is no trouble at all, and looks very well.

Now, take *large* seeds (beans, peas), tubers (oca, potato, jerusalem artichoke), small plants (herbs, tomato, celery, lettuce, cabbage) and small potted plants. Set them out as follows: With your hand, burrow down a small hole to the base of the loose top mulch. Punch or slit a hole in the paper, carpet, etc. with an old axe or knife. Place a double handful of earth in this hole, and push in the seed or tuber, or plant the small seedling in it. For seeds and tubers, pull the mulch back over. For seedlings, hold the leaves softly in one hand, and bring the mulch up to the *base* of the plant.

O.K. Instant garden. Time to retire. An important thing to do is to quite fill up the area with plants, according to the prior planting plan you had worked out on paper. For instance:

- chamomile and thyme near the path;
- larger herbs behind them (marjoram, sage, comfrey);
- potatoes and tubers behind this;
- small fruits and fruit trees at the outer border.

Any 'holes' can be filled with strawberries, cloves of garlic, onion plants, potatoes, or some such useful plant, at random.

If you must use small seed, do it this way:
Pull back the mulch in a *row;* lay down a line of sand, and sow small seeds of radish, carrot, etc. Cover with a narrow board for a few days, until seeds have sprouted (or sprout them first on damp paper). Then remove the board and draw mulch up as the tops grow.

Root crops don't do well in the first year, as the soil below is still compacted and there is too much manure, so they tend to fork out. Plant most root crops in the second year, when it is only necessary to pull back the loose top mulch to reveal a layer of fine dark soil.

By the end of the first summer, the soil is revolutionized, and will contain hundreds of worms and soil bacteria. Just add a little top mulch to keep levels up, usually a mix of chips, bark, pine needles, and hay. Scatter a little lime or blood and bone. For permanent beds, do no more, but annuals need occasional fresh mulch after harvest: their wastes are "tucked under" as are all your food wastes from the kitchen. Worms are so active that the leaves and peelings disappear overnight. Leather boots take a little longer, old jeans a week or so, and dead ducks a few days.

Whether from neighbours untended fences, or from the uncontrolled edge of your own cultivation, the mulched area of Zone I is under constant attack from ground invaders. In sub-tropical areas, kikuyu, couch or buffalo grasses reach out to smother the pampered annuals. Unless you can afford deep concrete sills under the fence, you must look to nature for the solutions.

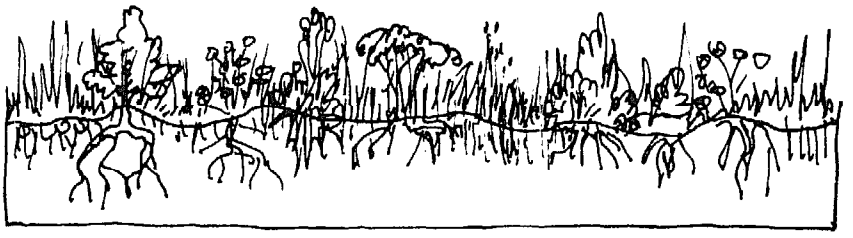
Lemon-grass, pampas, comfrey, bamboo, coprosma and like vigorous, shady or mat-rooted useful plants are immune to the re-invading kikuyu, and a short inspection of your area will reveal more species that do not permit the invaders' approach. So plant a living barrier around your protected area, mulch it well with cardboard, sawdust or straw, and rest easy from the labour of keeping your borders safe.

The same approach can be used to contain useful rampant species, so that blackberries can be confined to openings in forest, cumbungi (reedmace) to pond edges surrounded by ti-tree, and mint confined by shady dense bushes, rather than in tubs. Hens make a mess of mulch, but ducks can be released in mid-winter to clean up slugs and snails. Sawdust protects from slugs, lizards and frogs from woodlice and earwigs.

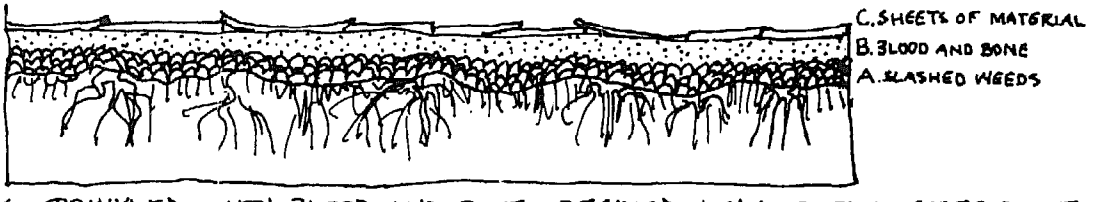
REPEAT SOWING:

There is no need to rotate plants in this system, or to 'rest the ground'. Potatoes are simply placed on top of the old mulch, and re-mulched. But then, there is no need to leave room to hoe or dig either, so plants may be stacked much more closely, but preferably in mixed beds rather than in strict rows. By frequent and random replanting, the garden will start to assume the healthy appearance of a mixed herbal pasture. The reasons for this "untidy" approach are clearly set out in this book, and are relevant to pest control.

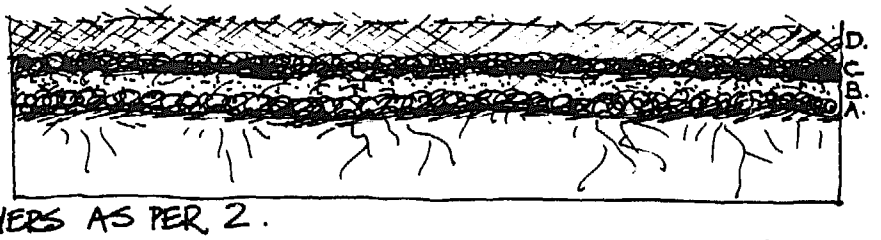
3.3



1 ROUGH ORIGINAL SURFACE WITH WEEDS, SHRUBS, GRASSES. STIFF PLANTS ARE SLASHED AND LAID FLAT.

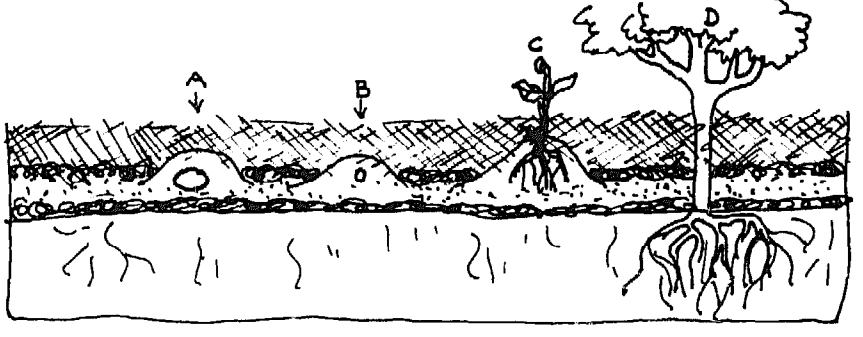


2 AREA IS SPRINKLED WITH BLOOD AND BONE, DECAYED LEAF OR THIN SCATTER OF FOOD WASTES PLUS SOME LAWN CLIPPINGS. THEN CARPETED WITH OVERLAPPED UNDERFELT, OLD CARPET, OLD LINO, CARDBOARD, NEWSPAPER 3 OR 4 LEAVES THICK, OLD COATS AND CLOTHES, HARDBOARD, SOFTBOARD, GYPSUM BOARD OR LIKE MATERIALS. CRUSHED OR DARKENED GRASSES AND WEEDS YELLOW AND DIE, WORMS START WORK.



3 A: LAYERS AS PER 2.
B: 75mm OF SEAWEED, STABLE SWEEPINGS OR MANURE.
C: "HARD" LAYER OF PINE NEEDLES, SEA GRASS
D: COSMETIC LAYER OF CHIPS, BARK, SAWDUST, COCOA BEAN HUSKS, RICE HUSKS, ETC.

} ALL WEED FREE



4 APPEARANCE OF PLANTED AREA, FIRST YEAR
A TUBERS, B LARGE SEEDS, C SEEDLINGS AND HERBS, D TREES AND SHRUBS ALL NEWLY PLANTED AS SOON AS MULCH IS COMPLETED.

FIG. 3.3: SHEET MULCH.

Some strong weeds may force through. Carry some damp newspaper and a bucket of sawdust. Push the weed down in the mulch, put damp paper on its head, cover with sawdust. If (perhaps) 10% of the kikuyu or twitch comes up, sheet with paper and again, cover with sawdust. All eventually die out under this treatment, leaving the area clear of all weeds: only your plants have their heads in the air. Another ploy is to dig up dock roots, bury kitchen scraps there, and re-mulch.

WATERING:

Water only when needed; that is, if plants wilt. One drought summer in Canberra ('77/'78) the Anderson family garden survived all summer with *one* watering about Christmas time. Feel down in the mulch, and if it is damp at base it doesn't need water. Most of your work is in extending the system, filling in spaces with useful plants, and designing the plantings or harvesting. Keep the garden full at all times. In the first year, however, you need to water more frequently, as the rotted and hygroscopic layer of fungal hyphae and plants at the base of the mulch are slow to develop. Newly planted seedlings need water initially, as in normal gardening.

Trees make quite phenomenal growth in this system, and bear several years earlier than in clean-tilled ground. The soil improves permanently. Trees may never need fresh mulch, as in a few years the larger trees and shrubs become self-mulching, the herbs hold their own, and only the annuals need annual attention. Potatoes are picked, not dug, and the mulch kept up close to them to prevent greening-off. They also do better in the second and subsequent years.

Never bury sawdust or chips; just put them on top where atmospheric nitrogen breaks down the wood. Worms add sufficient manure to supply the base manure. Keep the mulch loose, don't let it mat, and thus mix lawn clippings or sawdust with stiff dry material like chips or pine needles, bark, etc.

This system works. Observation and trial are the rules. Try a small area first, extend later.

Now, a little reflection will reveal the social benefits of a domestic sheet mulch. By using all organic wastes productively, you make the grade from consumer to producer, and the very nature of your garbage pail alters to harmless materials. If you extend the mulch out the front gate onto the nature strip, so much the better. Chris Stoltz, of Ballarat, did this and soon became a lesson in productivity and an inspiration to his neighbours. The mind boggles at the end result of mass urban mulching.

SOME SURPRISES:

In a few months you will note many free tomatoes, cucurbits, tree seedlings and the like spring up from your mulch. These arise from your garbage pail, or can be deliberately broadcast-sown, as sheet mulch is the best way to propagate healthy plants. Judicious thinning, replanting, gifts, and sales dispose of the surplus seedlings.

Yet another effect of litter and mulch is outlined in *Habitat* (V.4 of May, 1977, pp. 16-17), where the problem of *Phytopthora* (otherwise known as dieback, fire-blight or cinnamon fungus) is discussed. Litter and mulch preserve soil organisms, and the steady temperature and moisture conditions which encourage other organisms hostile to the *Phytopthora* fungi. Burning opposes this effect, which explains why well-mulched gardens are less likely to be affected by disease than logged, roaded and burnt forests, and why potatoes grown in mulch are often disease-free and "blight-resistant".

Somewhere (never in peasant lands) people started to separate medical, food, honey-producing, aromatic, and annual vegetables into distinct areas. Modern gardening books seem to encourage this, showing neat plans of categorized layout—kitchen garden separated from orchard, orchard from herb garden, herb garden from annual border, border from pond, pond from cacti, and so on. We recommend a total re-integration as the best method of pest control, stability in system, and beauty in landscape, with rare massed planting for special and pest-free species (bamboo, marigold, gooseberry).

3.3 1 Living Mulch

Another way to protect desert and tropic soils is to develop a living mulch. Charlie Snell, at Whims Creek (W.A.) writes that he has large orders for Sturts Desert Pea, for just such usage. Ruth Geneff of Perth (W.A.) is using *Kennedia prostrata*, again for mulch in which (or through which) she plants a garden. *Dolichos* species serve the same purpose in higher rainfall areas.

If we can develop such nitrogenous shady matting or carpeting of earth, fertility will build, and we can follow with other species. The leaves and stems of droughted ground cover build to humus in time, and pioneer species can take hold. Fukuoka[1] well describes how he converted hard red clay back to orchard using lucerne as his pioneer species.

2 Stone Mulch

In stony deserts or dry slope areas, where surface stone is readily available, stones alone make a permanent mulch around trees. Richard St. Barbe-Baker (*Science Show*, A.B.C., May 26th, 79) instances this technique as particularly beneficial to saplings in desert areas. Stones are of benefit to plants in the following ways:—

- by providing shade from intense day heat;
- by releasing stored heat to the soil at night;
- by preventing poultry or small animal damage to roots;
- by preventing wind lifting of roots;
- by providing shelter for worms and small soil organisms;
- and on very cool nights, by causing water to condense on their surfaces.

A variation on this is the "black mulch" of oil-bitumen wastes used in broadscale desert plantings.

3 Keeping Your Annuals Perennial

There are several techniques developed by gardeners throughout the world to keep annuals in the garden 'turning over'. Leeks are a good example, for if a few are left to run to seed, then lifted, many small bulbils can be found around the base of the stems. These can be planted out in the same way as onion sets, and as Fukuoka[3] points out, leeks should never be absent from a well-managed system.

In the onion/leek group of plants, many are in any case perennial. Near the door we can plant two varieties of European chives (coarse-fine leaves), asiatic garlic chives, and shallots of various types. Further away, as a border, set out potato onions (which give about 25 for every one planted), Welsh onions, evergreen bunching onions, the top bulbils of tree onions, and plant the cloves of garlic in the strawberry patch in autumn, or any space left in raised beds. Garlic bulbs, if allowed to multiply for two years give a constant crop.

If the large pods at the base of broad beans are left to dry and hay-mulched in late summer they will resprout in autumn; or the crop may be pruned back hard after harvest and will sprout again. Corn is a good interplant for summer. Seed potatoes can be left under mulch to sprout in spring, and lettuces let go to seed will scatter seedlings around their base for replanting. Parsley and many flat-seeded species reseed freely in mulch, and their seedlings can be set out to grow.

Fruit and vegetables (tomatoes, pumpkin, melon) placed whole under mulch at harvest ferment and rot, throwing up seedlings for new plantings. Some people keep carrot tops in a dark or cool place, let them sprout again, and set them out to grow in soft soil. Others cut their cabbages low, split the stalk crosswise with a knife, let small sprouts start, then divide up the stalk and root mass and replant. All these methods eliminate resowing or making seed beds, and keep the garden turning over crop.

In temperate climates the axil shoots of tomatoes and related species can be pinched out and reset as small plants all summer, the last lot potted and brought in to fruit over winter. Peppers treated in this way may be winter pruned and then set outside in spring, and sweet capsicum served the same. 3.3

Some useful species of annuals (chickweed, amaranthus) need to be encouraged to persist, perhaps by a little soil disturbance or mulch under the seedling plant. Anderson[7] notes how amaranthus is thus grown as an 'encouraged' rather than a cultivated vegetable grain in Central America.

A small proportion (about 4-6%) of all crops sown can be let run to seed or ripen for scattering under mulch, rather than buying annual seed crop. The key is to mulch with soft weeds, hay, and like plant material rather than to turn the soil and clean-cultivate.

4 BROADSCALE TECHNIQUES

4·1 PLANNING AN EVEN FODDER DISTRIBUTION

The age-old problem of a seasonal fodder or forage shortage is illustrated in Fig. 4.2. Both annuals and perennials in pasture reach peak productivity in spring, with a lesser autumn flush of growth if there are early rains. This at least is the regime of the temperate lands, where winter rainfall dominates. The data presented here is for south-eastern Australia, and appears in *Pasture Branch Bulletin* No. 3 of the Victorian Dept. of Agriculture.

Flock management, as the sale of young stock or the culling of herds after breeding, reduces the summer feed requirements. But it is obvious that there is a shortfall in midsummer and midwinter feed, the former because of summer drought and the latter due to the cold and slow growth of plants.

It is from data like this that the intelligent agriculturalist can plan tree-crop infills to take up the gaps that pasture alone leaves. For example, midsummer feed is provided by carob and honey locust pods, the foliage of *Coprosma,* pampas and *Chaemocytisus,* and autumn/winter feed by the same foliage plants plus the great variety of oaks, chestnut, and black walnut. Both these types of feed are basically concentrated and high-energy foods, enabling the more efficient use of dry pasture or rank grasses.

Traditionally, and in areas subject to drought, the foliage of kurrajong, willow and poplar has been slash-felled to tide herds over drought. It is far more sensible to use self-feeding systems under forage forest, and to plant strips of low forage foliage where herds can be turned in for short periods.

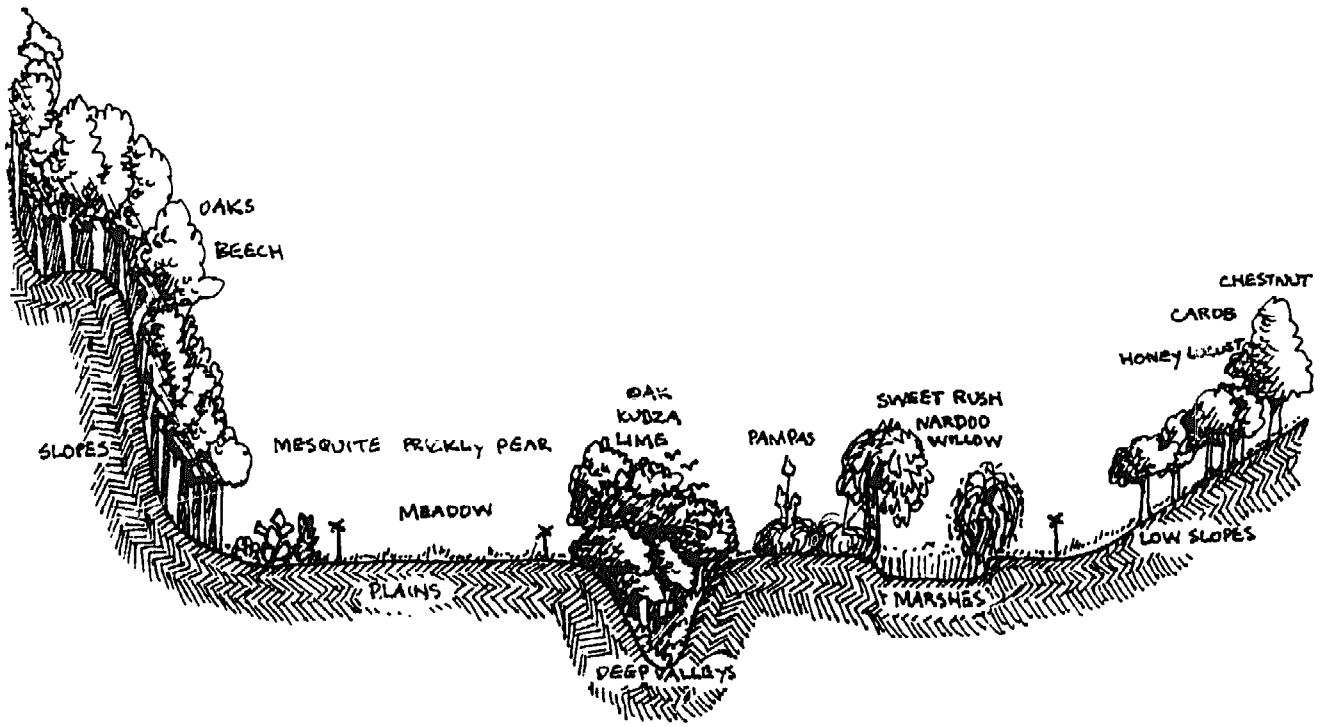


FIG. 4·1: ROUGH FORAGE (CATTLE/PIG) SYSTEM WITH BEES.

Schematically we can "level out" forage production to approximate stock needs, as per Fig. 4.1. A gradual (4-10 year) changeover to the correct balance of tree crop species would obviate the need for expensive forest harvesters, feed-grain storage and processing, and hay-making that is an essential part of "pasture only" farming we see today. It also suits the comfort and well-being of animals, who can range into forest when extremes of heat and cold affect them, and occupy pastures in the tolerable periods of spring and autumn. One imagines that this was, in fact, the normal habit of cattle and other large herbivores before we clear-felled farms for pasture, and that the non-functional hedgerows of today are the remains of the older forests. 4.1

As a secondary effect then, less stress is placed on the herds from heat and cold shock, and far less energy is needed by the farmer and the flock over the whole year. An estimated 15% of beef yield is lost due to lack of shelter alone. St. Barbe-Baker asserts that where 22% of the land is planted to productive trees, yields double on the remaining 78% of the land surface, so that no yields are lost by farm forestry, and the gains depend on design planning. If such systems were evolved on a broad scale it is probable that the extremes of drought and flood would also be modified by the forests, and the whole region would benefit from the pasture/forest polyculture.

What few farmers plan is a long-range policy of diversification, and this is just what is achieved by forest-pasture planning, as the tree products such as carob and chestnut can also be more directly converted to sugars, fuels, glues, food additives, flours, and such products. This is of great value when markets for wool, hides, and meat are in flux, and gives the forest farmer a very great advantage over the "pasture only" addict, who is tied to a single market or product.

How the changeover might be made is suggested in the following section.

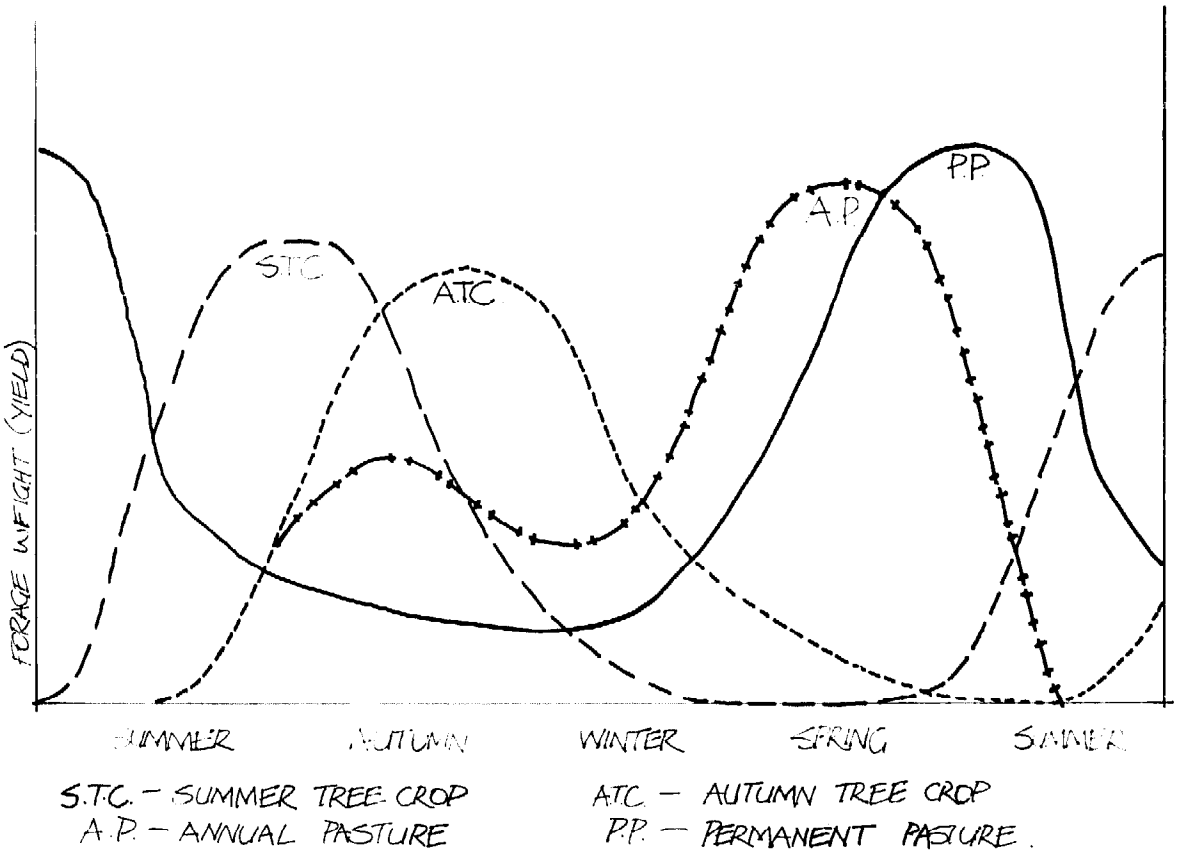


FIG. 4.2: SCHEMATIC OF EVEN YIELD FORAGE OVER YEAR.

4·2 ROLLING PERMACULTURE FOR LARGER PROPERTIES

All large properties, of about 20 ha or more, have areas which can be fenced out with minimal productivity loss. This is particularly true of steep, stony, eroded, or problem soils, awkward corners, and cold or windswept valleys and rises. Such areas permit the development of a rolling permaculture which initially provides shelter as hedgerow, and later becomes a diverse forage and tree crop resource.

The first narrow, or nuclear plantings should contain many species in almost random assembly, fairly thickly planted so that thinnings are available for pole timbers. Processes are:

1. Reduce pests by broadscale control or netted fencing.
2. Prepare land by soil rehabilitation and liming.
3. Accumulate seed supplies, and plant many species for later assessment. (Select good seed and give necessary pre-treatment (soaking, boiling etc.).
4. Mark selected strong seedlings with pegs for later mulching and experimental treatment with fertilizers (seaweed solution, blood and bone, stable or poultry manure). An excellent ploy is to mulch within empty tyres around trees. This protects from wind, rabbits, and drought. Thorn or thistle mulch in tyres discourages small browsers.
5. Gradually introduce poultry or light livestock into the area, watching for damage.
6. Assess and shift or add fences as the system proves itself.
7. Cull poorer specimens for pole timber, leaving selected high-yielding or strong trees and shrubs to continue growth.

A rolling permaculture has the following beneficial effects:

- provides a sheltered nesting, lambing or calving place, and increases meat production;
- enables early diversification into honey and pollen production;
- enables later diversification into a wide range of animal and plant products, nut crops, etc.;

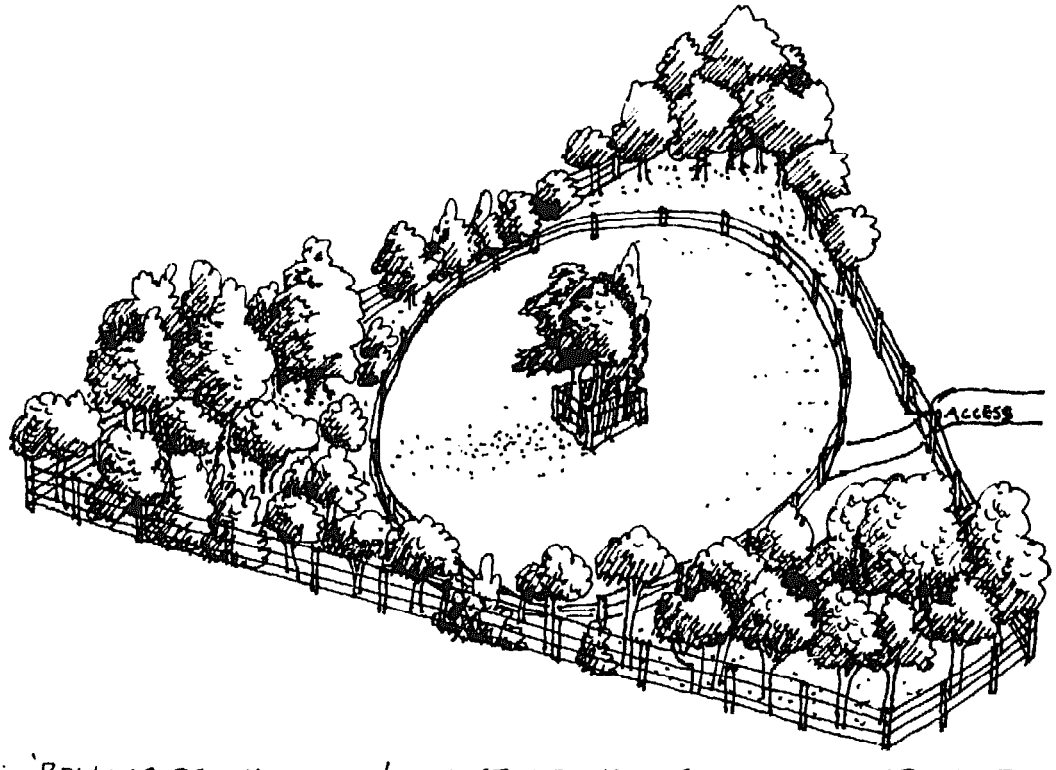
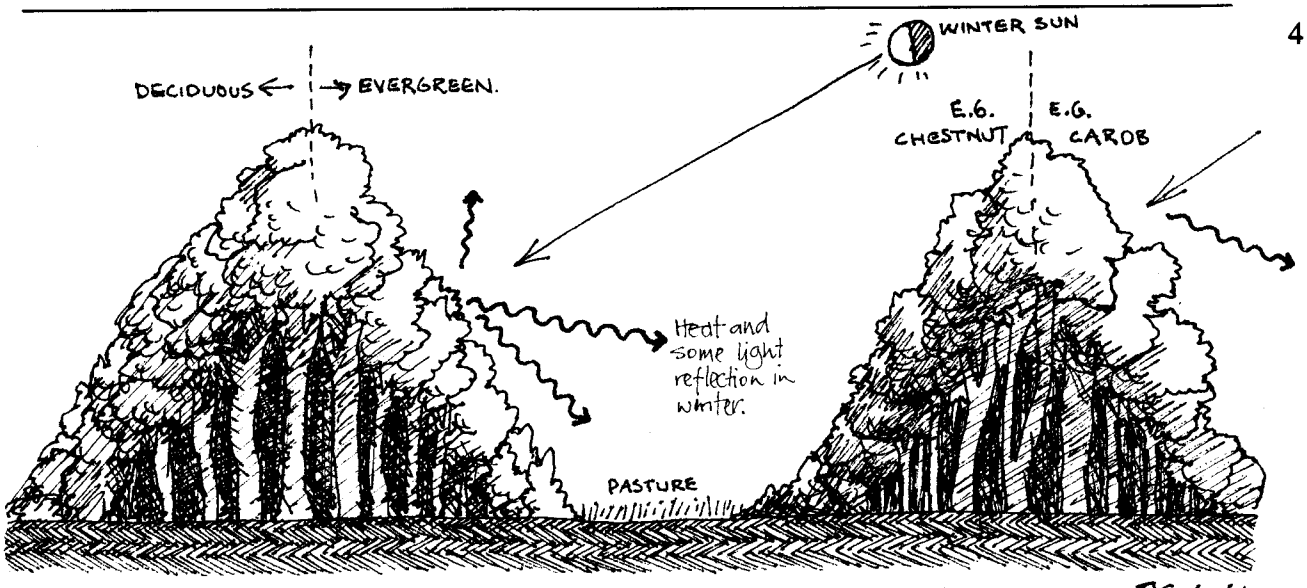


FIG. 4·3: 'ROLLING PERMACULTURE' — PASTURE ELECTRIC FENCED AT CENTRES; AWKWARD CENTRE AND CORNERS PLANTED TO TREE CROP, FENCES TO BARRIER SPECIES.



IDEAL STRUCTURE OF TREE CROP SPECIES ON PLAINS. DECIDUOUS SPECIES TO SOUTH (N.), EVERGREEN SPECIES TO NORTH (S.). TREES ACT AS WINDBREAKS, HEAT REFLECTORS, STOCK PROTECTORS, CLIMATIC BUFFERS, CROP DIVERSIFICATION, POSSIBLE FUEL PRODUCERS, EROSION PROTECTORS, DROUGHT-PROOF STOCK FEED. FIG.4.4:

- buffers climatic effects, particularly that of drought. This alone may double yield in protected fields;
- provides on-farm liquid fuels after simple distillation;
- prevents soil erosion, especially wind erosion and water loss;
- reduces need for heavy fuel consumption as annual crop is reduced in area;
- reduces groundwater table and prevents salting of soils; and
- provides drought-proof and cold-proof concentrated feed for stock in periods when pastures are at low yield.

In a world governed in its economics by the cost of energy, farmers need to be fully aware of the potential of polyculture. A one-bet system can fail on one factor. As a local permaculture is zoned, so are farmers zoned from market, hence, supply centres. Increasing distance means increasing cost and greater reliance on home production of vital materials, especially manures and fuels. Attention should be given therefore to the tree species selected, with respect to local needs and distance from the market.

1 On-Farm and Urban Production of Fuels from Plants

It is taken for granted here that every farmer needs to be a gardener, for if his commercial enterprises founder on fuel costs or markets, then at least he can still live off (and on) his farm. The importance of the house and garden goes beyond this, however, as it is in the garden and nearby that he can try out small-scale techniques of low-energy agriculture to be applied to larger areas, and produce the seedling trees and shrubs for permaculture planting.

The critical importance of low or no-tillage grain and starchy root crops, of sugar-rich carob beans, plums, or sugar cane and beets is that all can be fermented to alcohol fuel. Every householder and farmer can thus produce a clean-burning fuel for cooking, light, and essential transport. Most areas have (legally or illegally) a gifted distillation expert, although (not surprisingly) we hear little of this as a government-encouraged enterprise. It is the very basis of self-reliance that is available from such crops, and the pay-off is that the protein value of fermented foods is not reduced, but enhanced. (Dried waste grains yield 20-25% protein.)

4.2

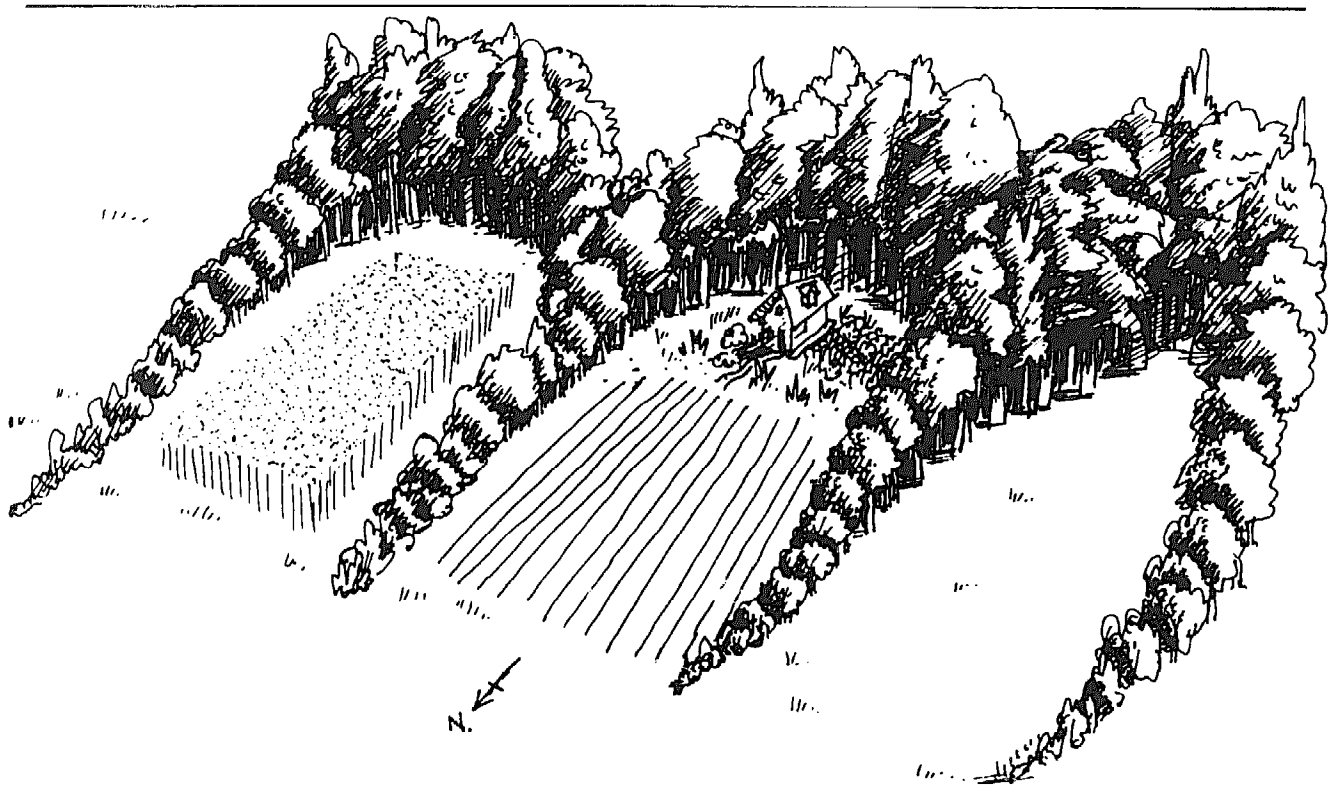


FIG. 4·5: BASIC SUN TRAP STRUCTURES FOR HOUSE, FIELDS.

Simple amylase columns (pipes filled with amylase culture on glass beads or quartzite pebbles) convert cellulose wastes to glucose, hence alcohol, so that a grinder converts garbage and straw to fuel with no great problem.

Housed in a greenhouse, the by-products are heat and CO_2, mulch and food. No critical materials are lost, but all products not directly utilised can be recycled via animal feed (pig, worm, fish) to plant food, thus closing a solar cycle that will fuel every tractor or motorbike needed for essential use. The technology is simple, well-known and widespread.

Any details we have on this process are updated at intervals as a standard design (see Appendix I). Only very simple tools are needed (mainly tanks). A simple flour and water dough may be used to seal any vents in stills, and it is humbug to pretend that any community cannot easily produce a liquid fuel, plus the basis for stock feeds, preservatives, cooking fuels, and so on. The delay is, one must believe, due only to the unwillingness of public utilities to give up on centralized and polluting power, and of government support for oil companies, not people or farmers.

Australia (*ABC News*, July, '79) will spend 2-3 million dollars on P.R. to save petrol, but the same amount spent on the low-cost ($15,000) distillation plants that would make a community or small town self-sufficient is "not available". The intention is obvious: we are expected to stick with petrol or gas products, lead and pollution, until the oil companies gain control of alcohol fuels.

Most high-performance cars now run on alcohol, as do 60% of Brazil's vehicles. But the pretence is that we need "research" to develop this in Australia. Hogwash! Again, the only possible response is to build our own local plants and to resist central control, as this would mean great energy waste in the transporting of raw materials to process plant, and alcohol back to farm. On-farm production and roadside sales are the real solution, and one which is now available.

Dr Dick McCann, from the Dept. of Chemical Engineering at Sydney University, speaking on the ABC *Country Hour*, July 19th, 1979, reports on a simple still he has developed for on-farm use, and gives some yield figures for fuels from crop. He estimates that 5000-8000 l/ha/annum

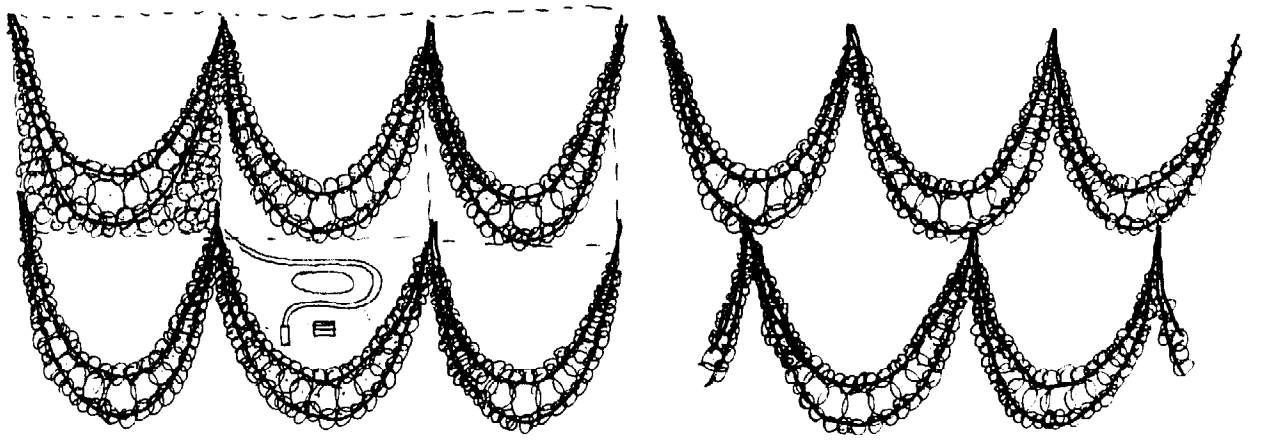
(450-720 gall/acre/annum) from sugar beet, and a tenth of that for wheat (500 l/ha/a—45 gall/acre/ann). Thus wheat or grains give a lesser yield, but still give a more useful residue for stock feed; any area where sugar cane or sugar beet can be grown has the advantage of a product with a direct ferment to alcohol. Grains, wastes and cellulose must go through other preliminary processes such as sprouting, boiling, grinding and enzyme activity to first produce glucose or sucrose before fermenting to alcohol.

Any group of farmers could easily fund an on-site tank, as could any small town. About 5-10% of farm land devoted to fuel production would provide fuel self-sufficiency, with some surplus. Less area would be needed if we develop tree crops, and less again if that crop is carob or sugar-producing tree-crop. Farmers and city waste centres are the potential future energy base for essential fuels. For lubricants also, castor oil and jojoba products suffice. With bicycle "freeways" increased and more efficient rail, canal, and sea transport and solar power, any society would be self-sufficient in the essential transport needs. Like small stills, small hydro-electric plants are possible, though as yet these have not been mooted, although many farms and towns have nearby falling water or swift-flowing streams. Again, the problem is the centralization of power in large utilities. We may yet live to think of the "petrol crisis" as a blessing, if it leads to sane regional self-sufficiency, or a curse if it leads to the use of atomic power and a desperate scramble for the world's remaining fossil fuel resources.

The fact that some 20,000 U.S. farmers now use on-farm stills should put an end to the excuse of "further research" and any delay in implementation of this renewable resource. On vehicles, Victor Papanek of Wisconsin, has developed a very light "fibre-grass" car, the body made from local grasses and a modern glue. Fueled with alcohol, this vehicle would serve farm transport needs in both the west and the third world. Like the old Baby Austins, such vehicles need only small (5-7 h.p.) alcohol motors, but modern design gives them greater efficiency than the older vehicles.

Perhaps the most cogent argument for alcohol fuel is that the insidious lead pollution from car exhausts is eliminated, thus alleviating health hazards in cities. The long-term advantage is that the heat budget of the planet is not adversely affected, hence the threat of climatic change due to the burning of fossil fuels and the felling of forests is also avoided.

Looking at unemployment, there could also be positive spin-offs in this area. Every 6-10 ha devoted to fuel production would support a family, and any farmer would find it worthwhile to employ (or lease out land) for fuel production. The same employee or producer could plant long-term crop in the time available between annual beet or can crop: such species as carob would be invaluable for fuel as the beans are 68% sugars. Thus fuel forests could be established on each



NETWORK OF SUNTRAP/WINDBREAK PLANTINGS. LEFT HAND PATTERN APPROXIMATES FENCING IN RECTANGULAR FIELDS. FIG 4.6

farm that needed collection rather than annual cultivation and manurial input. The by-products of increased glasshouse production and high-protein animal or human food would pay production costs, so that such fuel is free to the producer. If the monies now devoted to the creation of new (and unpopular) freeways were diverted to local alcohol-producing plants, the evils of unemployment and the "energy crisis" with its accompanying expensive fuel, would disappear, and we would have time to think again. In suburbs, all food and cellulose wastes could be used to generate fuel *via* amylase columns, and end the humbug of "waste disposal" costs.

Sometimes one can be pardoned for thinking that we are all crazy, or dumb, or that there is a gigantic conspiracy to keep people down and out. I am inclined to think that both factors are operating.

4.3 ORCHARDS

Except for the scale of the plants, orchards are little different from pastures. The legume/tree mix parallels the legume/grass mix of permanent pastures, therefore we can best commence any orchard by planting legumes—small species like white clover, lab-lab and lucerne, larger acacias, albizias and locusts, and a scattering of leguminous shrubs.

The second element, after legumes, are scavenging poultry. There is no reason at all why the legumes chosen to support the orchard should not also support poultry on range. Even cursory observation will reveal to any interested person that fruit and nut species under which poultry or small livestock (wallaby, sheep) are allowed to range are more vigorous, healthier trees, showing less lichen, dead branches, and very little, if any, insect attack on fruits. Conversely, trees or orchards where cattle or horses are allowed to browse show severe damage and disease. In permaculture then, the orchard is planned as a poultry range, so that the larger perennial legumes (locusts, tree lucerne, Podylaria) are interplanted not only for nitrogen fixation, and to break up the monoculture, but to provide poultry fodder as seeds and berries. All fruits are useful fodder, but elderberry, mulberry and *Craetaegus* species are of high value.

For some reason, litter under poultry-run trees is more plentiful; that is, natural mulches are thicker: Leaf mould is constantly being turned over by hens, suckers from trees are less, and water absorption of the soil better, while grass mats are rare and many persistent weeds are absent.

The process to follow is simple enough: prepare the whole site by soil conditioning, set out the leguminous species, and interplant the selected orchard trees, allowing small animals to forage below the system as pest control and manurial elements. Pigs (autumn), geese (winter) ducks and poultry (all year) are suitable livestock. Tree lucerne (for bees) top-trimmed as goose forage in winter, add nitrogen and provide bee fodder, and control ground pasture. Hazel as edge species, small fruit understorey, and perennial flower or vegetable crop for "in-line" plantings are also helpful.

Trials of black, red and white currants, gooseberries, lucerne, tree lucerne, clover, narcissus, perennial dahlia, jerusalem and globe artichoke, ugni, and the like will reveal successful species for site. Any deciduous trees removed as diseased can be replaced with evergreen (feijoa, citrus, loquat, olive) and the situation varied by long-term interplant of chestnut, walnut, almond and plum.

Should you be so unfortunate as to inherit a monocultural orchard, remedial measures follow much the same plan: add 3-4 hens, a pig, and 5-6 large wattles per 1000 m^2 (¼ acre), with many smaller legumes. As decoration and variety, plant fuchsias, banksias and *Knifophia* for the insectivorous birds; borage and white clover for the bees, and keep a keen eye on developments, using judicious mowing and adding more species as the system evolves.

Planned variety gives a good display at wayside stalls and enables direct marketing of varied products, from flowers to fruit and nuts. Precisely the same number of fruit trees can be grown for commercial use, even though the acreage may need to be expanded to accommodate the inter-

plant species, but savings in pest-infestation and fertilizer use more than compensate for the need to disperse the system, while secondary yields increase the total income, and free the producer from the fluctuations of a commodity market or a rapacious processor.

PRUNING – NECESSITY OR HABIT ?

Almost all fruit trees available from nurseries have been shaped in such a way that later pruning is essential. Most books on tree culture give data on pruning. Few bother to question why a tree is pruned, but some reasons are as follows:

- ease of spraying and harvesting;
- maximum size of fruit;
- reduction of leaf and increase of fruit spurs;
- even ripening due to even light penetration;
- removal of diseased parts; and
- small tree size for small areas, greater density.

All of these are admirable ends, if the aim is a commercially produced and even product. They are not necessarily the aims of permaculture. Unpruned trees have the following features:

- less risk of disease from cut surfaces;
- smaller but more numerous fruit, greater yield per unit;
- stronger frames;
- fit into mixed forest, crop, animal husbandry; and
- uneven ripening, more difficult harvesting or spraying.

Ladder and windfall harvest, self-harvest, and far less work offset most of the latter setbacks.

WOODLOTS AND HEDGEROWS 4·4

Like "free-range" poultry, farm woodlots may be frequently mentioned but seldom specified as to their use on farms. Rather, farmers are encouraged to plant trees suited to central processing for wood pulp, or for off-farm, commercial markets. However, many on-farm needs also exist, and these may be:

- fuel (from high sugar crops);
- structural (fences and buildings);
- forage (winter and summer feed); and
- shelter (which can be provided by species suited to forage or structural use).

Some very valuable trees, such as black walnut, not only produce young trees for structural use, but may be sold out as rootstock for grafting, and at maturity enable the farmer to retire on the crop income (timber of great value).

For structures, species of long natural durability in the ground are first choice. Such species are listed below:

Very High Durability

(70 years or more in the ground)

*Strawberry Jam Acacia	(*Acacia acuminata*)
*Black Locust	(*Robinia pseudoacacia*)
*Catalpa	(*Catalpa speciosa*)
Almost all cedars	(*Cedrus* spp.)
Juniper	(*Juniperus communis*)
River Red Gum	(*E. camaldulensis*)
Huon Pine	(*Athrotaxis franklinii*)

*Signifies species recommended as multi-use species. (See Schery, R. W., *Plants for Man,* Allen and Unwin, 1954.)

4.4 Long Durability

(30-70 years)

*Chestnut	(*Castanea dentata*)
*Red Mulberry	(*Morus rubra*)
*Osage Orange	(*Madura punifera*)
Bald Cypress	(*Taxodium distychum*)
Redwood	(*Sequoia sempivereus*)
*Honey Locust	(*Gleditsia triacanthos*)
*White Oak	(*Quercus alba*)
Tasmanian Tallowood	(*Pittospoorum bicolor*)
Macrocarpa	(*Cupressus macrocarpa*)
Oyster Bay Pine	(*Callitris tasmanica*)
Desert Oak	(*Casuarina decaisnea*)
Celery-top Pine	(*Phyllodadus rhomboidalis*)

No doubt this list can be greatly expanded, but from any such list the farmer can choose shelter-belt, hedgerow, and cattle or poultry forage species, bee forage and plants which yield foliage or fruit for distillation (as oils or alcohols). Some suit arid, others riverine or coastal conditions. Some (most of the conifers) are useful mainly as timber, and are therefore less generally useful in the system, as well as being slow-growing.

Plant barriers may be erected, with or without supporting fences, for a variety of reasons:

- to contain or exclude livestock;
- to shelter gardens and houses from wind;
- to increase the efficiency of wind and sun;
- to prevent re-invasion by unwanted plants; and
- to screen unwanted views and sounds.

It is the first of these categories that is most difficult to satisfy. Almost the only tree I know which stops everything, but needs no pruning is *Lycium ferocissimum,* or African boxthorn, and it will stop bulls, lions, and weed invasion, resist salt spray and gales, and feed poultry (the latter also disappear into it without recourse). In coastal sandy areas, the crown tends to spread gradually to about 7 m wide, and plants may seed down, but the cost of uprooting seedlings every 50 years or so is small compared with the frequent attention needed to keep less ferocious hedgerows tight. This, then, is the ultimate hedge-barrier for broadscale, large livestock containment. Cautious browsing by stock sometimes occurs, but an established *Lycium* hedge is a stable, wide fence. In pastures and on heavy soils it has no tendency to spread as seedlings.

Lycium compounds or 'bomas' of dead branches will protect plantings of more useful trees, and clipped branches will deter rabbits if strewn around seedlings. Others recommended jujube and *Rosa multiflora* or *Rosa rugosa* for equally formidable barriers, both need hard stopping or pruning in their first few years. Logsden (that useful man) also reports glowingly on Osage orange (*O.G.F.S.,* America, May, 1978).

Hawthorn (*Crataegus*) species live-set at (60 - 90 cm) and later layered or interwoven with dead trimmings is the traditional livestock hedge of Europe (and Tasmania), but needs cutting to shape every 4-6 years. All such hedges are made more efficient either by a few strands of barbed wire strained through them in their infancy, by ditch and bank approaches, or by permanent electric wire protection.

Logsden also includes the redoubtable and never-browsed red cedar, the honey locust and shingle oak (*Quercus imbricaria*). Cacti too are effective in dry areas, as are unpalatable or thorny local species.

Inside the more impenetrable hedges, only woven or netted palisades repel small livestock, but I have seen these made as tight as baskets in the Caspian Sea area, where living papyrus uprights, interwoven with dead stems, are used. The beautiful middle-European woven fences illustrated by Williams[9] have been duplicated by Tagari, using local wattle, ti-tree (Melaleuca) or 'whipstick' regrowth, and of course bamboo would serve equally well.

Combination weave and thorn quickset hedges are fairly quickly established, but for the non-grazier (most of us) less fierce hedgerow is needed. Prockter, in his most useful book on garden hedges, gives a wealth of detail and species for a great variety of soils and exposures, with much data on hedge propagation. 4.4

So much for the exclusion of livestock; we come now to plant barriers as windbreak systems. It is essential that windbreaks do what they are intended to do, that is, break the force of the wind, as well as performing as many other functions as we can build in. Some of these are:

- act as firebreaks where this is a crucial factor;
- store up emergency fodder for a variety of animals;
- make it easier to cultivate, or to use implements;
- provide bee forage and insectivorous bird cover and nesting sites;
- give at least some cull wood for construction timbers;
- contain at least some species which can be used to diversify farm product in emergencies; and
- conserve soil and clean run-off water, and prevent erosion.

The shape of the windbreak should be very much that of the "sun-trap" shown in Fig. 4.5. (Trellis on walls, earth banks and dam spoil will create other and more local suntraps.)

When we come to *productive* wind shelter (cattle excluded) mixed hedgerow of *Prunus, Crataegus, Coprosma, Malus* (crab apple), hazel, bamboo, fuchsia and vines are wonderful wildlife and forage habitat. Again, enclosures of bamboo or "fields" of pampas grass, paspalum, sudax, ti-tree and like thickset species are essential winter shelter for newly-shorn sheep, ewes in lamb, or for emergency snow retreats for wildlife. In dry areas we look to tall tamarisk, casuarina, mulga (*Acacia aneura*), eucalypt and similar drought-proof trees to protect the soil from dessicating winds. This also applies to the reduction of evaporation in open ponds.

Within the confines of the annual garden, clipped *Coprosma,* tree lucerne and *Leucaena* supply not only wind protection, but manurial mulch for their leaves and branchlets, or material for the strawyard.

Against the burning of salt winds *Coprosma, Euonymus japonicas,* sea buckthorn (*Hippophae lamnoides*), "fedges" of scramblers such as *Tetragonia implexa* and tall stands of pines are our defense.

Temporary summer windbreaks are provided by sunflower, jerusalem artichoke, belts (not rows) of polebeans and corn, and autumn-winter clumps of broad beans. But in very severe winds perennials are necessary. Tiny hedges of clipped rosemary protect small herb gardens and *Escallonia macrantha* or wormwood gives a soft silver edge to seaside gardens.

A certain series of plants will halt invading couch grass, twitch, oxalis and the like; these have either matted roots (bamboo, pampas, lemongrass) or have very dense foliage (*comfrey, Coprosma, Lycium*). Of such hedges we can border our inner mulched and controlled areas. Some of these barriers can be "reinforced" with marigolds (against twitch) to the inside, oaks and pines without, and so resist or totally prevent ground-weed incursions into gardens.

5 DESIGN FOR DIFFICULT CLIMATES

Climate, even more than landscape and soil needs specific design. For all practical purposes, man lives and gardens in only three broad climatic regions:

- the temperate and sub-tropical areas of winter rain and hot summers (the area most considered in this book);
- the tropical humid areas of summer rain;
- and the arid lands, where rain is irregular but may come as flash floods or sudden downpours.

Cold deserts, arctic and mountain climates, and equatorial jungles are little occupied by man, and thus play little part in the world economy, although all have useful plants. Coastlines are not climates as such, but have many common aspects, and share with deserts the problems of wind and salt, so that coasts in general deserve specific treatment. In the following section I will deal briefly with the tropical and coastal lands, and more extensively with arid areas, as these are of greater extent in Australia and the third world.

5·1 ARID LANDS

Perhaps the most pressing problem of the third world, and of much of the western world, is the rehabilitation of arid lands. Once the trees have been totally removed, the goat and camel flocks have killed all regrowth and the soil blown away or salted, re-afforestation is a problem. So is gardening. And yet, like all problems, we can find solutions. Some of these lie in studying the techniques of oasis dwellers like the Papago Indians of Tucson, described by Andersen:[18]

> "Those clever agriculturalists grow ancient crops, specialized kinds of corn, beans, and squashes which will produce a useable harvest on fewer inches of rainfall than are used anywhere else in the world."

Few nations are showing the positive approach of the Chinese, who use straw mats to subdue sand dunes, and plant millions of trees in their baskets through this stable cover (having now abandoned the folly of trying to grow grain on these areas).

There are two approaches to the arid lands, neither as yet tried on a very extensive scale:

- using species and techniques of known effect (as for the Tucson Indians);
- devising new techniques in the modern idiom (as for the bitumen "mulch" used in Morocco).

Both need to be used in any integrated approach to desert rehabilitation. Although we have impoverished the flora and fauna of many deserts, we can recombine the remnant species of all deserts to make a rich agriculture. My own limited experience with Aboriginal Australians trying to farm in very arid conditions prompts the strategies given here.

The text which follows is derived from a report to the agricultural advisers of the Australian inland, completed by the writer earlier this year. Interest in the strategies noted has been high, and the original report is therefore collapsed into this book for more general use. Some plant species have been added to the original, and the whole may make a small contribution to third-world desert reclamation. Emphasis is on Australian species and problems, and particularly the social issue of Aboriginal nutrition and survival.

The strategies outlined derive from visits to the Ernabella and Papunya settlements of central Australia, and other journeys to western Victoria, West Australia and arid N.S.W. Problems of the desert and semi-desert are sometimes shared with humid areas (winter frosts from April to September, compacted soils, fragile sandy areas) and are otherwise peculiar to tropics (termite attack on living trees) or to deserts themselves (heavy populations of feral donkeys, horses and cattle).

At Ernabella, the annual rainfall varies between (at worst) 50 mm and (at best) 640 mm. An average of 250 mm therefore means little and is locally irrelevant if the run-off from rock domes and the reserves of water in river-beds, at bores, and in dunes or dry river sands is taken into account.

Where we have hills, there is a well-marked frost-line at about 9-15 m elevation on slopes, so that "tropical" and "temperate" crops are both possible on the same slope. 5.1

The broad strategies of desert re-afforestation are now well tested. Hostile drying winds, rivers, and local oases are the focal points for expanding the vegetation: if we start from up-stream, securing the headwaters and catchments, from up-wind, and from oases, then plants generate moisture downstream, down-wind, and locally.

In many areas, run-off from bare or rocky areas increases effective precipitation, so that small areas of a few acres to fifty acres or so may be selected where good underground or runoff water is available for gardens. Rock-holes, some small dams, rock seepage, underground water in soaks or sandy river beds, bores, wells, windmills and tank-water from roof catchment all assist gardens, and run-off properly directed would make gardening possible in many places. The aim is to use many more deep-rooted and climatically-adjusted perennial plants for food and structural materials, in order that desert outstations may become more self-sufficient, and to devise low-maintenance systems of domestic agriculture.

The less these methods rely on sophisticated machinery, transport, and fossil fuels, the better it will be for future survival, so that more natural methods take preference in view of the state of the petrol economy.

The native vegetation of all deserts still presents a great resource, although fire/grazing interaction and the presence of very large numbers of feral livestock and (in some places) rabbits, makes for great difficulty in establishing new plantings unless these are well-fenced and protected. Treeless areas are evolving due to overgrazing after fire. Many small native animals are scarce or locally extinct due to foxes, dingoes, feral cats, wild dogs, and the large feral species of herbivores.

Camp dogs in and near settlements keep feral grazing species at bay, and after recent rains around Ernabella there followed a dense regrowth of saltbush, acacia, and river red gum. But these same dogs also present problems with new plantings and with poultry, although older people cling to them for night warmth in camp conditions.

First, I must state that in my opinion, based on real examples sighted, that the "dead centre" is a myth. Not only will many important vegetables and tree crops grow in deserts, but the native vegetation, where not overburnt or overgrazed, is, in itself, a great resource.

Water lies close underground in many places. Mulch material, as plants or leaves, is abundant. Growth in desert soil is phenomenal if water is available. Modern drip-irrigation plus mulch will grow any domestic crop. While lawns, as such, are rather wasteful disasters, the potential is for a revolutionary forestry, and thus increased rainfall, and a reduction of dust and disease. China is planting 7,600 km of her desert fringe; Australia could do the same, but hasn't as yet started on the first 7 km, preferring to have an unemployment problem, dust, salted soils, and large profits for a few graziers! There has been little or no attempt to develop large desert water storages, or to encourage scour-hole lagoons, and no extensive use of keyline or Negev run-off techniques, although road graders are now available for such work.

The potential is great, but funding and government support are not very evident to this year. The outstanding movement of the Aboriginal people has enormous possibilities for pioneering arid-land agriculture, and should be funded and supplied with the necessary species and materials, as a valuable contribution to our fundamental knowledge of the great areas of arid lands here and overseas, and for the evaluation of techniques for use on a wider scale.

The sad present condition is that most food, not of good quality due to transportation difficulties, is imported to settlements, and as petrol becomes scarcer and more expensive greater hardships will result for all sectors of the population. Therefore there cannot be too much emphasis on trials of new species on a broader scale and an emphasis on home gardens rather than commercial plantings is needed at this stage (these latter may come later as a result of the smaller trials in gardens and after the basic survival of residents is assured).

For Aboriginal lands attention to cultural differences is important, if not critical, to the acceptance of new techniques. We can make too much of this, however, as people such as Horace Winitja at Ernabella, Johnny Kantawara at Warren Creek, and many others not mentioned are in fact producing good gardens of annuals, and the demand for trees from the nursery at Ernabella

4.4 exceeds supply. Two factors need to be accounted for: one is the rightful authority of guardians to protect any sacred sites, or direct the sort of gardens that are to be tried nearby; the other is the "sorry camp" which means that all people move from a place where someone has died. The former does not exclude very much land from tree crop considerations, and the latter may be accounted for by the establishment of a separate "sorry camp" nearby gardens. The sacredness of certain trees like the native fig (*ili*) in some areas must also be respected, although this does not preclude usage as a vine trellis while elsewhere it may be used in more profane ways for hybridization or rootstock.

PLATE 5.1: KIM TJITAYA IN THE NEW NURSERY AT ERNABELLA. CONCRETE REO. MESH FORMS WALLS OF SUCH STRUCTURES, SHADE COVER AND OVERHEAD SPRINKLERS ARE ALSO USED. SUCH NURSERIES CAN BE ERECTED AT ANY OUTSTATION.

Children need the same familiarity with cultivated species as they have with wild plants, and this will come in time as trees become more common (the habit in wild gathering may be to break off a branch and pick fruit from that). Certain vegetables are unfamiliar, and need to be 'learnt' before they are food, or are picked at the right stage. There are, nevertheless, many favourite foods in cultivated fruits and nuts, and experience will give skills in using these. 5.1

White ants (termites) are a problem peculiar to tropical Australia, ordinary ants, in great quantity, another; eel-worm (nematodes) is a pest in market gardens at Alice Springs, and cabbage moth is generally distributed. Hawk moth larvae attack vines, as ever, and dogs make it difficult to keep small livestock. Fruit-fly is a problem in some areas, but is local in distribution. Absent are possum, blackbird, starling, sparrow and other such nuisances of the temperate grower.

Fencing, mulch, tree polyculture practices, and the use of forage poultry under tree or vine species would greatly reduce all pests. Many hardy tree species seem, in any case, little-affected. Local pest controllers such as *Moloch horridus,* the ant-eating *Mingari* or Mountain Devil may be of help, as would guinea fowl. Marigold (*Tagetes*) control 90% of eelworms, and these together with pyrethrum daisies may help with termites. There are many termite-resistant trees in the area. Wallflower extract helps with cabbage moth control (blended and sprayed) and other natural controls could be tried. Mike Lubke (N.S.W.) reports that they are attracted to, and lay eggs on, the Datura Lily (*Brugmansia*), but the larvae do not then pupate. Wood-ash and sour milk are also recommended by Neil Douglas, and the harmless derris dust is a complete control. Fruit-fly is not a problem in the presence of ground scavengers such as poultry, which also help with termites.

Local Strategies I

These fall under the following categories:

- home gardens for local survival (selected design in settlement);
- broadscale planting for climate modification
- run-off or local selected site planting.

HOME GARDENS:

Here the aim is to make gardening an integral part of desert living. Around the house (*wiltja*) in the pest-protected, fenced and guarded areas, where feral herbivores have least effect, rabbits are kept at bay by dogs, and most organic wastes accumulate. Water must be present for settlement to persist, and thus the wastewater from showers, toilets, and roof areas is available.

There is a combined aim in gardening: first, to use such resources productively, and second, to alter the house or wiltja climate while so doing. As in temperate areas, sheet mulch is an answer.

Useful species for mulch provision, and as street and garden shade trees are mulga (*Acacia aneura*), tamarisk, any of the desert oaks or casuarinas, and tall cultivated bamboo, grain or sugar cane wastes, *Paulownia, Acacia albida,* and *Leucaena.*

Trickle irrigation plus mulch is the key to water conservation, the reduction of salt and carbonate accumulation, and the buffering of pH values, as humic acids tend to offset the effect of highly alkaline soil. Ploughing only increases alkalinity to intolerable levels. Around wiltjas the area is swept free of burrs, and bones and ashes can be added to the mulch, as can the droppings of cattle, dogs, and other feral species. The result will be less rubbish for flies, thus less eye problems, less old clothes to carry scabies and attract pests. Heat plus water causes rapid breakdown of all materials mentioned. Topping up with leaves is the main maintenance activity. Few, if any, special tools are needed, and digging is superfluous.

House planning:

The following suggestions are made with a view to modifying the climate in and around the traditional house or wiltja. In so doing I am not implying that wiltjas are necessarily the most desirable of dwellings. The people themselves must be given the opportunity to decide the types of

5.1 structures they would prefer, and the funding to build them. Thus it is not suggested that well-designed houses are not needed at outstations, but that, at present, the existing structures could be more productively designed.

By erecting deciduous vine trellis (grape) or trees (*Acacia albida*) to the north, evergreen vine trellis as an arbour to the south (*Tecoma* vine does well here) the climate of the house is correctly modified. Vine trellis over wiltja roof, and ivy or trellis on house walls has a similar effect (Fig. 5.1).

Tall tamarisk, white cedar and giant bamboo could be used to screen cold SE winds and provide mulch, and light foliaged Paulownia or *A. albida* to the north providing shade for both house and crops also helps. In the cool arbours, strawberries, mint, blackcurrant, gooseberry and soft herbs will grow, again in deep mulch for water retention. The "*yuu*" or windbreak near the wiltja can be provided by smaller bamboo, or as screens to prevent cold air-flow along house walls in winter. Trellis and deciduous species provide shade to the north. If *Tecoma* or ivy grows over the roof, so much the better.

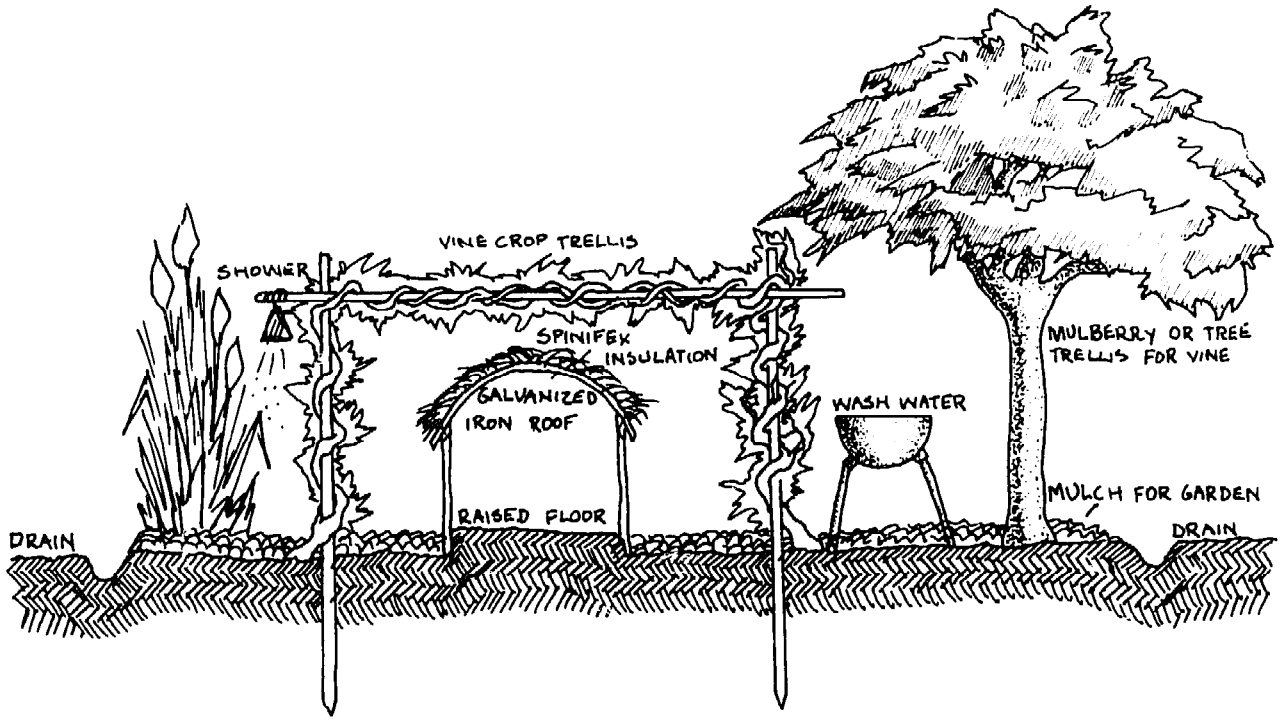


FIG. 5.1: SECTION OF IDEAL WILTJA.

A small or strongly-constructed roof can be soil-covered, mulched, and planted to ice-plants, cacti, succulents, and hardy desert species. Watered, these roofs yield cool air in summer, and act as external insulation for winter cold. Vines on walls, or on trellis set out from walls, have a similar effect on heat loss and gain.

The *Ngumpa* (shade house), *yuu* (windbreak) and *wiltja* (house) are fairly sophisticated designs for comfort. It may be advantageous to make these permanent 'grown' shelters (as per Fig. 5.1) for hunters or for overnight camps, especially if soil-covered and mulched. *Yuu* can be easily grown. These tactics save cutting mulga at camps.

All these strategies provide climatic amelioration and save fuel. A schematic wiltja (Fig. 5.1) could be tried out as an outdoor living environment. All suggested adaptations can be made to existing structures, or designed into new houses. At present, hot water from solar collectors is proving to be very satisfactory, and light for wiltjas from solar panels plus battery is certainly possible, as are solar-electric fences for wild cattle and camels. Dry toilet systems could be installed at outstations, or areas reserved for burial of faeces in tree-crop sites.

The *ngumpa* is used by Kim Tjitayi to shade his ducks. Traditionally these are thatched and sheltered with pole, spinifex piled on top. The same spinifex should go to mulch after use, and provides good insulation for roofing (Fig. 5.1). Ginger Wikilyiri is trying grape vine or trellis to evolve a shade *puri,* and there is little doubt that combinations of bamboo, trellis, spinifex and vine would make for very comfortable living outdoors, or as attached arbours on houses in hot weather. Andrew Prior is to try the modified "Mortlock" or tree-like trellis devised by Brian Coombs at Waite Hort. College, Adelaide. 5.1

In permanent houses shower water can be led to slotted pipe drains under the shadehouse or garden. At *wiltjas,* pebble mounds with showers overhead would provide water treatment and garden moisture for citrus crop or vines. Many showers, so placed, make garden watering an automatic process, and washing-up, shower, bath or washing water containing soap, led under mulch, is a benefit, not a nuisance. It is a matter of integrating the garden with the waste water from washing processes.

OLD MIKE AT KAAPA CITY OUTSTATION COMMENCES STRAW MULCH OF MELON PLOT. PLATE 5·2

Sewage and sullage:

5.1 The safest disposal of sewage is in pipes or trenches below plants. The lagoon or pond for soiled water at Ernabella is not yet planted, but is the ideal site for dates, plums, and peaches, both on the banks and around the pond, where the water seeps to the creek underground. Even the most paranoid of health inspectors would approve this safe conversion of waste water to vitamins.

Sludge from septic tanks can be let go into pre-dug planting holes, filled over, and dates, mulberry, or fig planted. Grapes bear fruit (from cuttings) in 18 months in this climate! Similarly, raked or mown plant material can be pit-mulched and covered near planting holes. Raking under bamboo or tamarisk serves too purposes:

- to provide seed-free mulch; and
- to protect the mother plant from fire.

Termite-proofing timbers:

Early trials of cold-soak (butt-soak) treatment for fence and trellis would save much timber in future. Bamboo, mulga and eucalypt should be butt-soaked in "Tanalith" before use. Present vine trellis is of radiata pine so treated, and should last indefinitely. Tanalith (copper-chrome-arsenic salts) is available from agricultural suppliers, and comes with an instruction booklet which should be requested. Treated timber is safe for children to handle, but should never be burnt as both fumes and residues are quite toxic.

This is an essential technique, as termites eat, in a few years, valuable posts which take forever to grow. Trellis and bean sticks also could be treated to advantage. Tanalith is also a handy 'paint' for exposed planks. In hot weather, a three-day soak suffices. Poles should be trimmed and cut to length before treatment so that treated waste is minimised. Bark may be mulched on gardens, as are (chopped) foliage and twigs, in orchard[17]. Many termite resistant species exist or can be grown.

Ideal relationships (water, etc.) Fig. 5.2

The ideal relationship of water, *wiltja* and garden is fairly clear. Any advantage of slope is ideal, so that settlements like Willy's at Ullumparu is a model. Here a rocky cleft was damned by hand (concrete and stone) to retain a clean clearwater pond. Overflow goes to a larger swimming

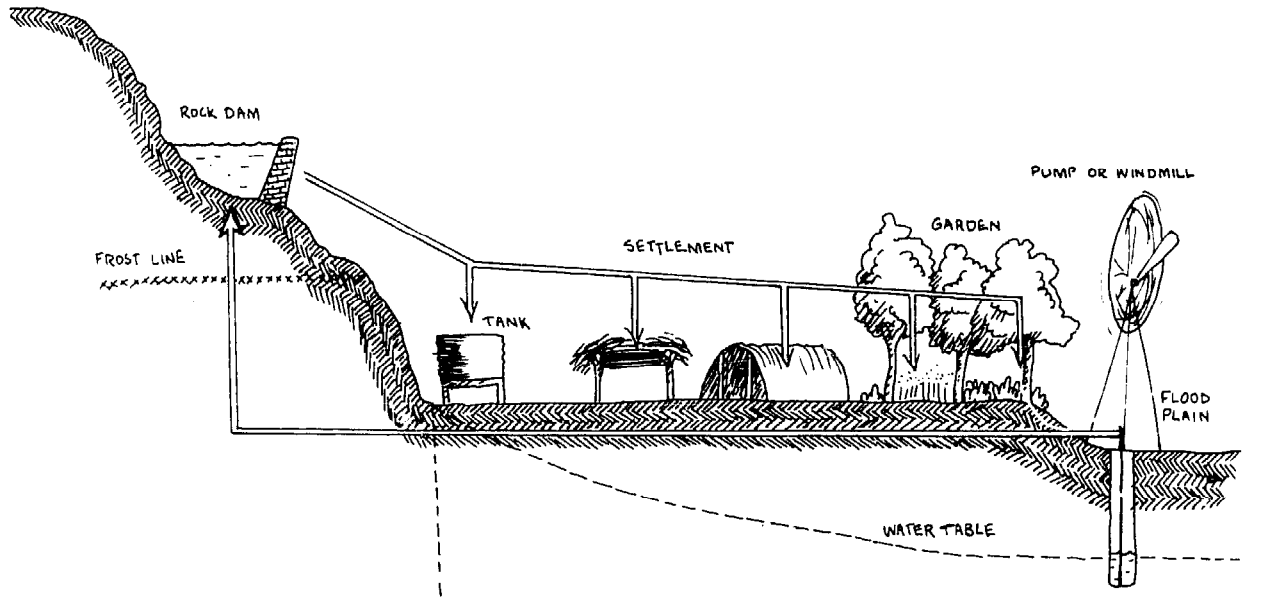


FIG. 5.2: IDEAL RELATIONSHIPS — WATER, SETTLEMENT, GARDENS FOR ARID LANDS

pool edged with sweet rush. From the top pond a pipe leads water over 1200 m or so to the *wiltja* area, at head. Showers can later be sited in the garden, and moved as trees establish around them. 5.1

Windmills (petrol-free) are very effective in raising water to height. Mike Last and Andrew Prior plan a 7.5 m model. This allows growing above the frost line (on hill slopes) of more tropical crop, further protected by *A. albida, Paulownia* etc. for frost protection. Guava, paw-paw and mango may then be grown on foothill or slopes. Neither high rock dams nor windmills need a great deal of attention; the gears of the mills lubricate quite well with castor oil, or jojoba oil, which also grows well in arid areas, and needs only a crude press to process.

Tanks on hills and ridges, if not covered, produce abundant green algae and mosquitoes. Goldfish (chinese carp) and grass carp eat both these nuisances, and provide occasional meals. Earth floors in tanks or dams also support freshwater mussels, themselves excellent water filters and food, and shell-grit for poultry. Native snails provide grit for ducks, who appreciate these pests. Mosquito control can be provided for by using small fish in standing water.

BROADSCALE PLANTING:

Bulk seed of, for example, date palm, jujube, cork oak, pistachio, plum, white cedar, tamarisk, sweet chestnut, honey locust, carob, mesquite, paulownia and bulk cuttings of grape, fig, tamarisk, mulberry and coprosma could be set out over trial areas, selecting niches for special plantings. Stone and desert pines would be a probable success on ridges, as would desert oaks. Asparagus may take well in river sands, where some wild plants were observed, and like hardy species also. If limited trials succeeded, these or similar resources could be spread on a broadscale. Burrs (for rabbits), cacti, and wormwood (not eaten by cattle) could help protect seedlings. Success may depend on the reduction of feral browsers, or on the protection of trees by natural thorn and rock-crevice situations. Plates or divisions of cacti would almost certainly succeed. The system is worth diversified broadscale trials.

Erosion control on dry slopes:

The "net and pan" planting pattern of Figs. 5.3 and 5.4 is an effective control in overgrazed, eroded, mined or bulldozed sites. If tyres are available, the "pans" can be made from these, filled with mulch, and the diversion drains led in above the tread level. Some fortunate people have access to logs, which can be staked cross-slope, on a slight downhill grade so that water is made to zig-zag across the erosion face, and hence absorb into the ground. Even small logs and branches, pegged across erosion channels build up a layer-cake of silt and leaves, beside which willow, ti-tree, acacia, or any other fibrous-rooted and hardy species can be planted, which then act as a permanent silt trap. Mulch behind logs and barriers quickly stabilizes the seed bed for planting. Fallen leaves and scattered dung also accumulate in these mini-deltas to provide plant nutrients.

On very steep slopes there is often no recourse other than to plant pampas, bamboo, and root-mat pioneers, and to make upslope plantings of chestnut, acacia, carob, olive or other large species which will cascade seed downslope over time. Where implements such as chisel ploughs can be used, the same pattern of net and pan is effective in erosion control.

What we tend to see however, are fairly massive contour trenches, allowing little soil absorption of water, creating dry strips on slopes, and exposing a great deal of subsoil; such heavy-handed approaches need massive machinery, and achieve little in the way of water control and soil improvement, compared with planned chiselling and planting, which makes a permanent and stable change on hillsides.

SELECTED SITE ENCLOSURES:

These apply to areas of high natural runoff, such as the base of domed rock, piedmont at valley mouths, rock seepage areas, and old sheep pens where large quantities of dung make underground water sponges. Andrew Prior and Kim Tjitaya are testing out several such sites with olives, pistachio, grape, mulberry, fig, and apricot, as well as adapting small rock domes by the

5.1 use of concrete gutters, hand moulded (Figs. 5.5-5.11). Such sites repay fencing to discourage large feral species. Solar electric fences would help, and outside barriers of cactus, jujube, wormwood and bamboo could be developed into barrier hedges. Evenari[23] and Yeomans[2] recommend that any area of runoff be in the ratio of 16 or 20 : 1, or that a dome of 8 hectares be led to a garden of 4000 m² (1 acre) or so.

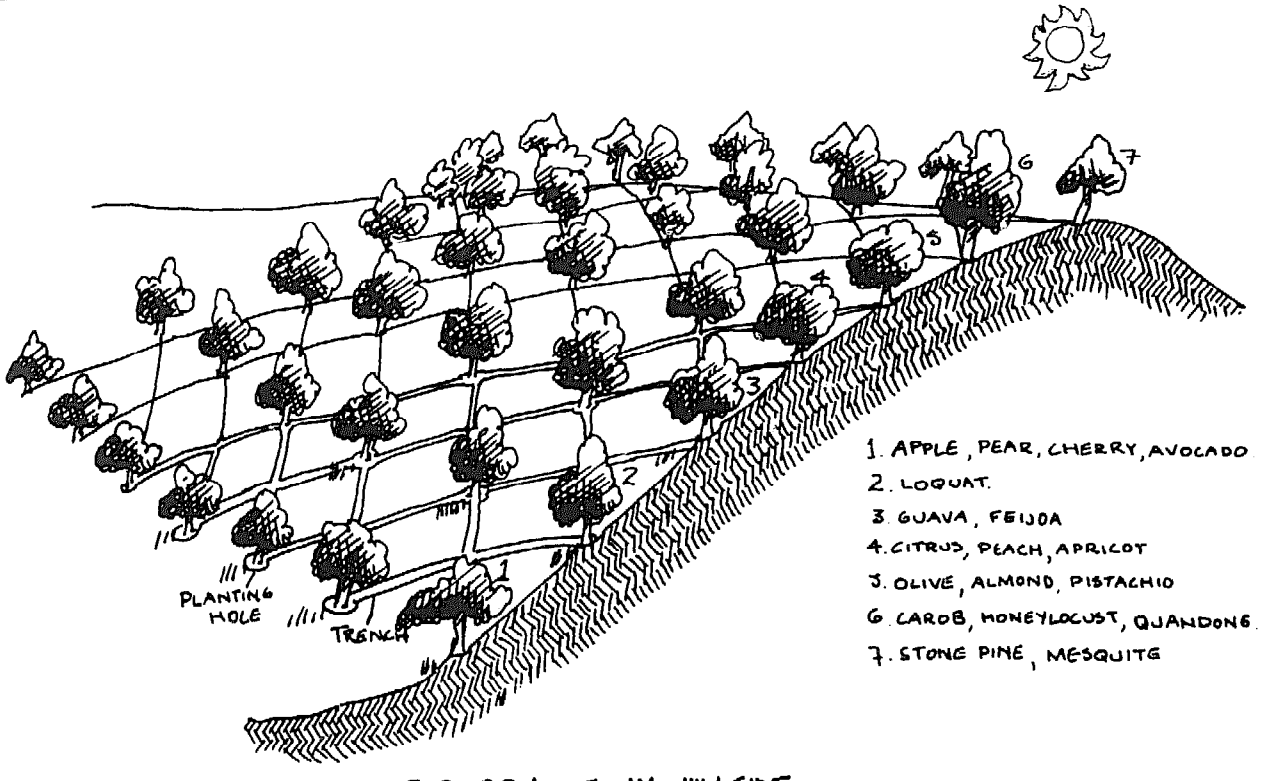


FIG. 5.3: NET AND PAN FOR DRY, STONY HILLSIDE.

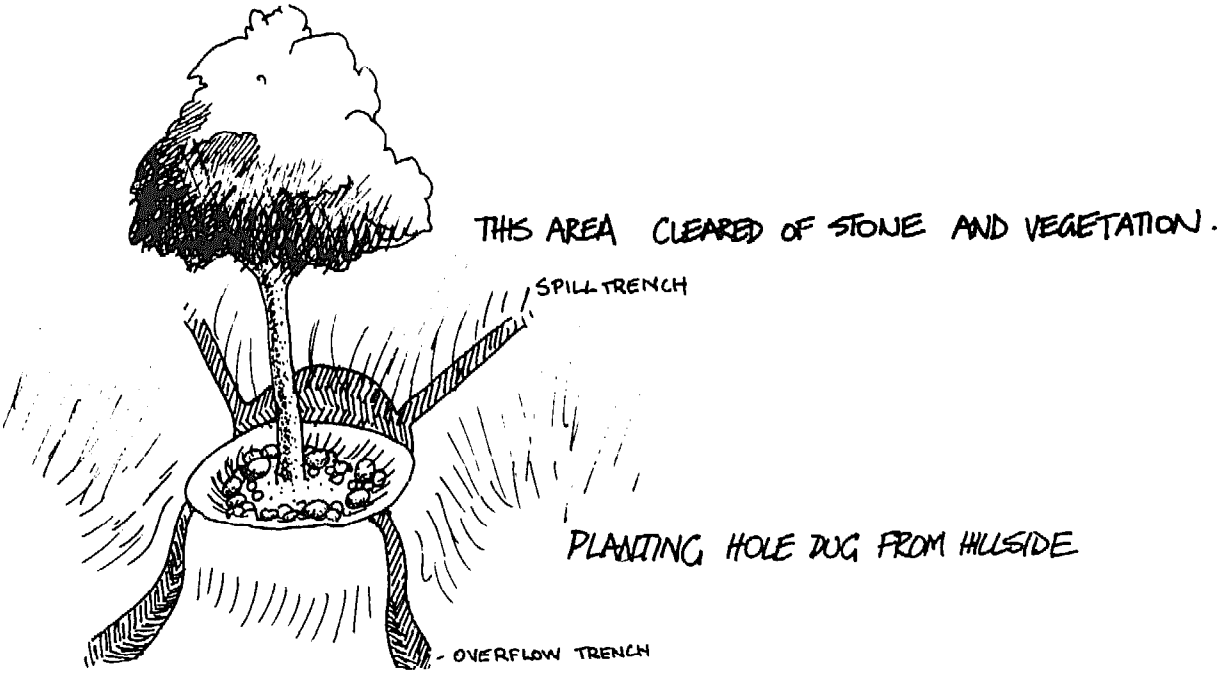
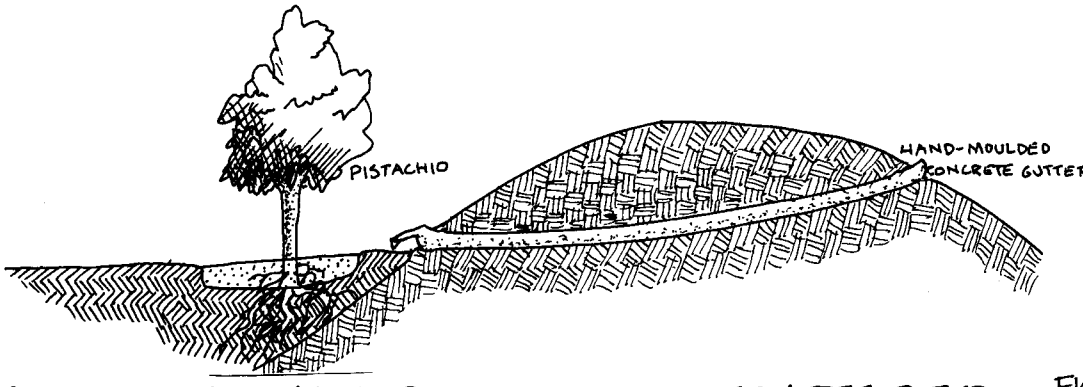
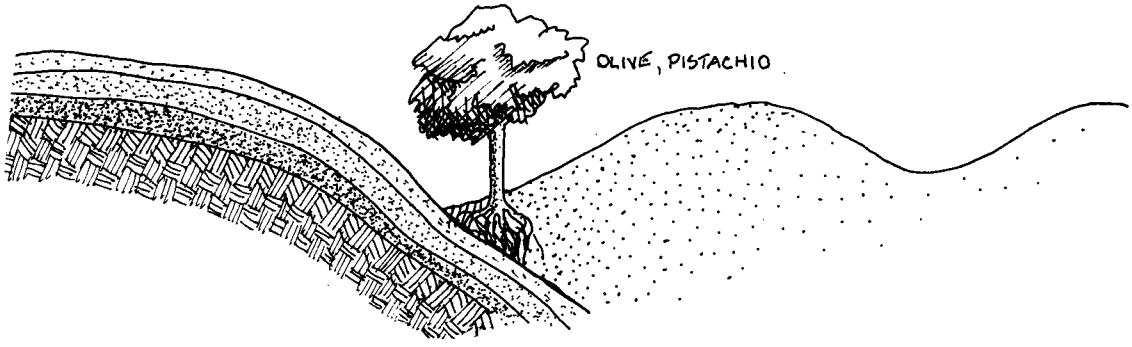


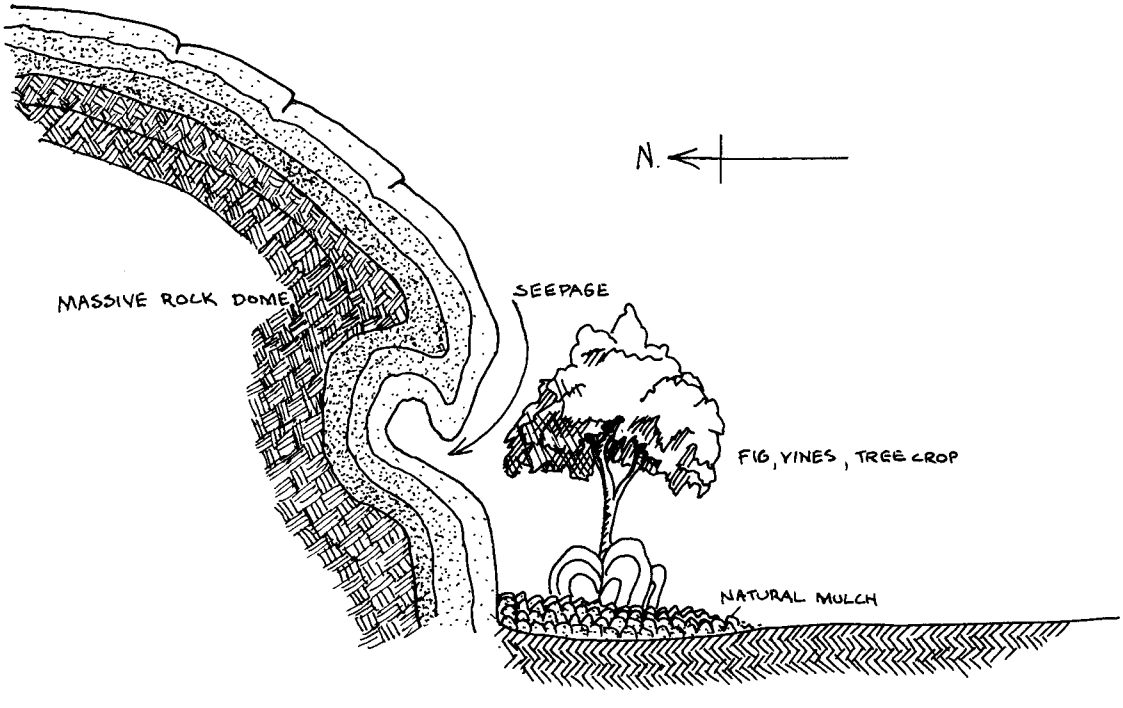
FIG. 5.4: DETAIL OF PAN.



AT WOMIKUTTA : SMALLER ROCK DOME SUFFICES FOR A TREE OR TWO. FIG.5.5



AT WOMIKUTTA: MASSIVE ROCK LEADS WATER TO BASE OF DUNES. FIG.5.6



AT KATJIKATJIDARA. FIG.5.7

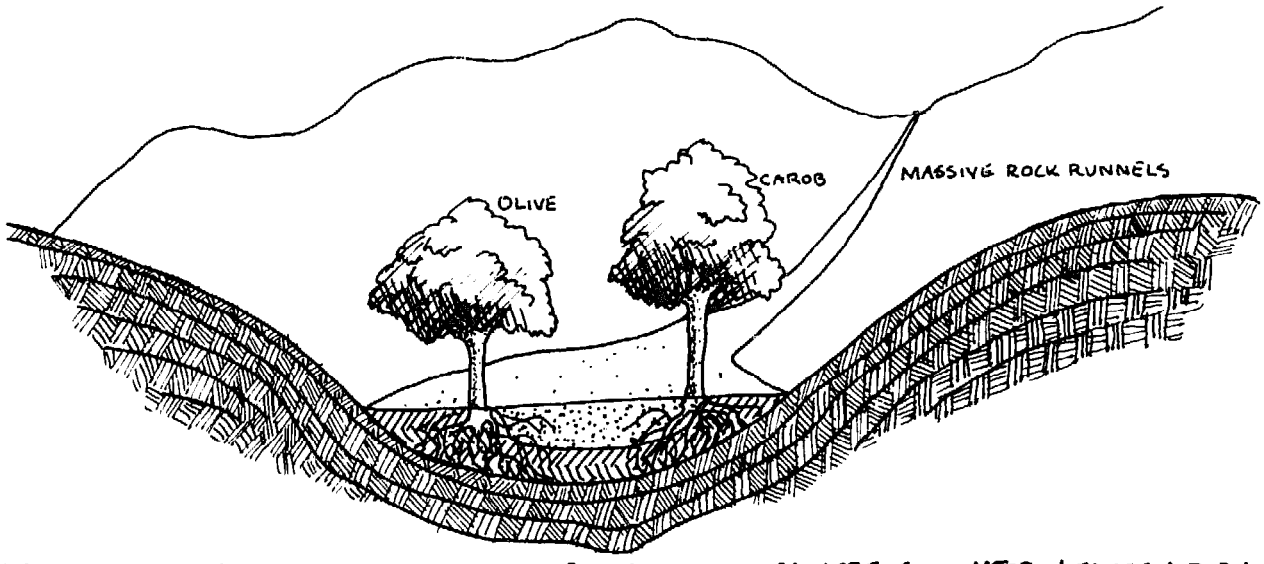


FIG.5·8: HIGH ON KATJIKATJIDARA: GULLY IN ROCK GATHERS SOIL, WATER, LEAVES AND DUNG. SUCH AREAS MAY BE TERMITE FREE.

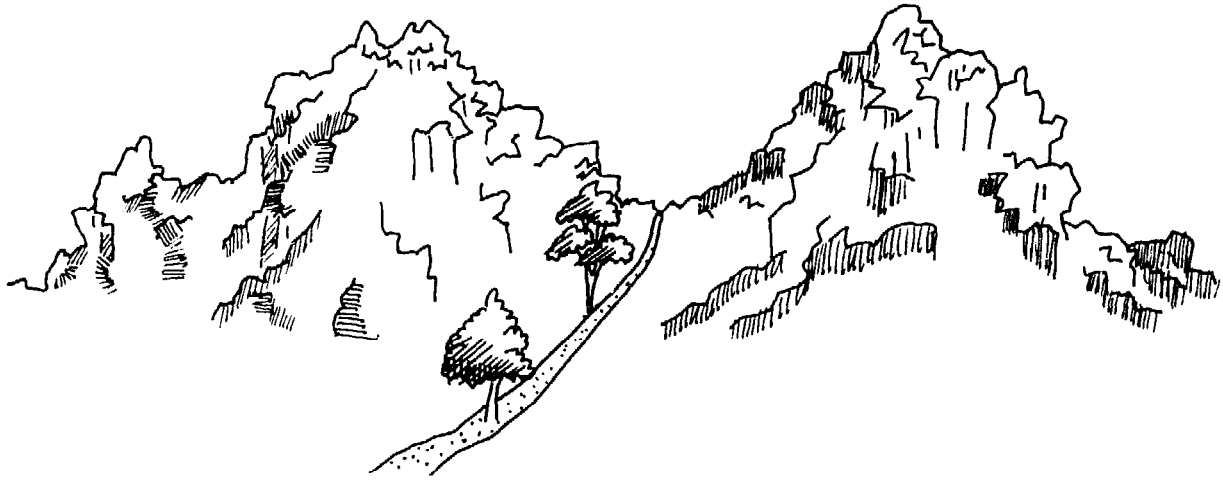


FIG.5·9: AT WILSONS CREEK: SANDY RUNNELS BETWEEN ROCKS STAY WET LONG AFTER RAIN.

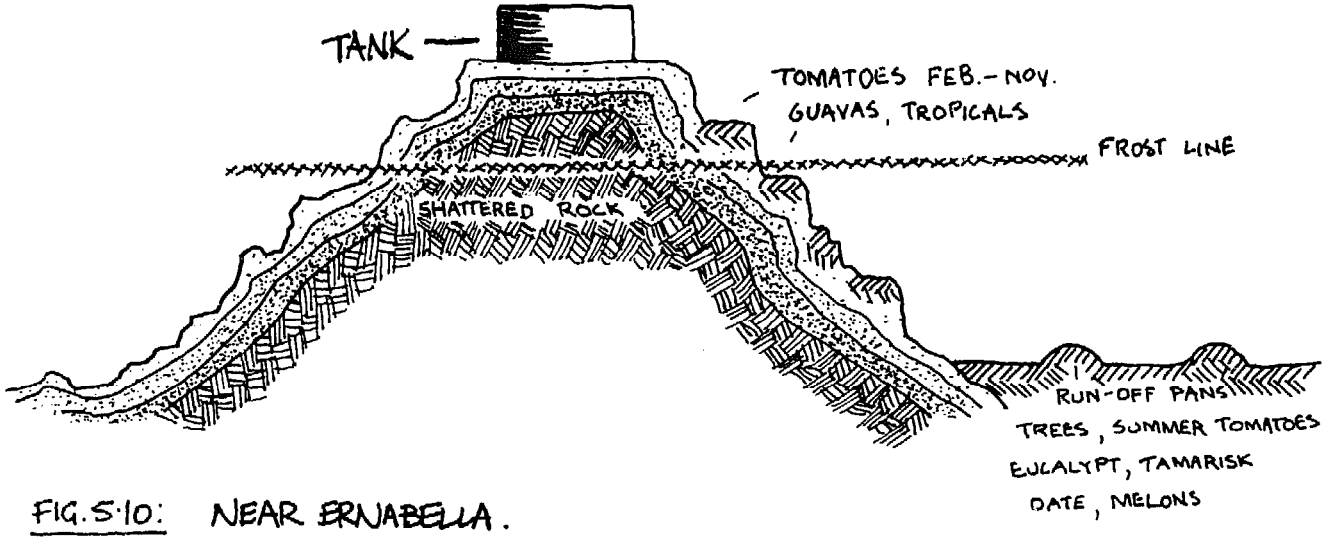
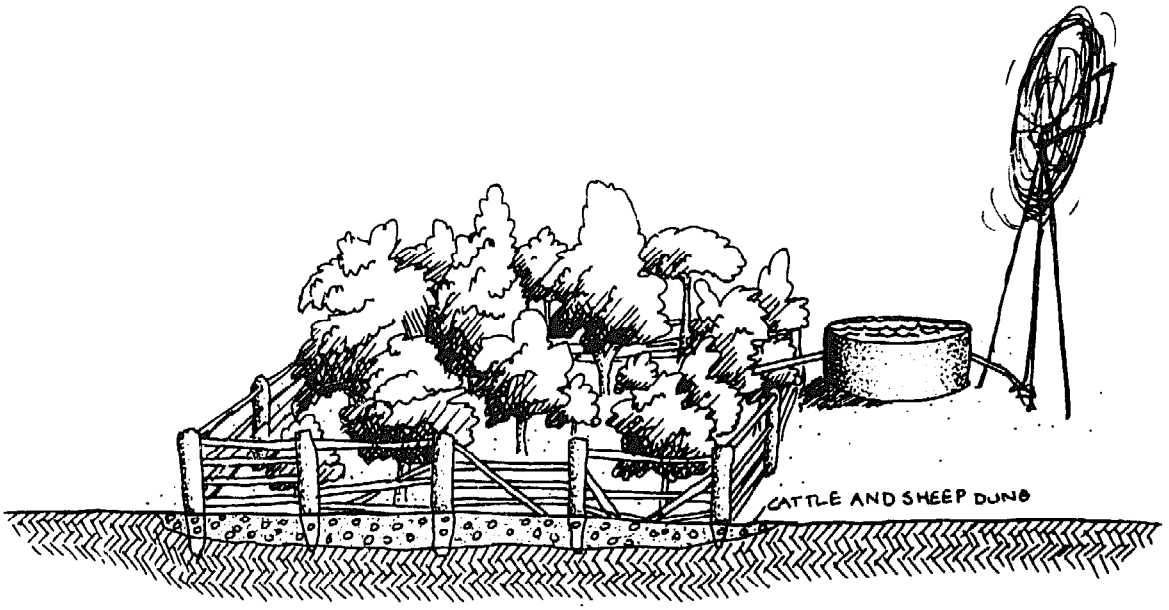


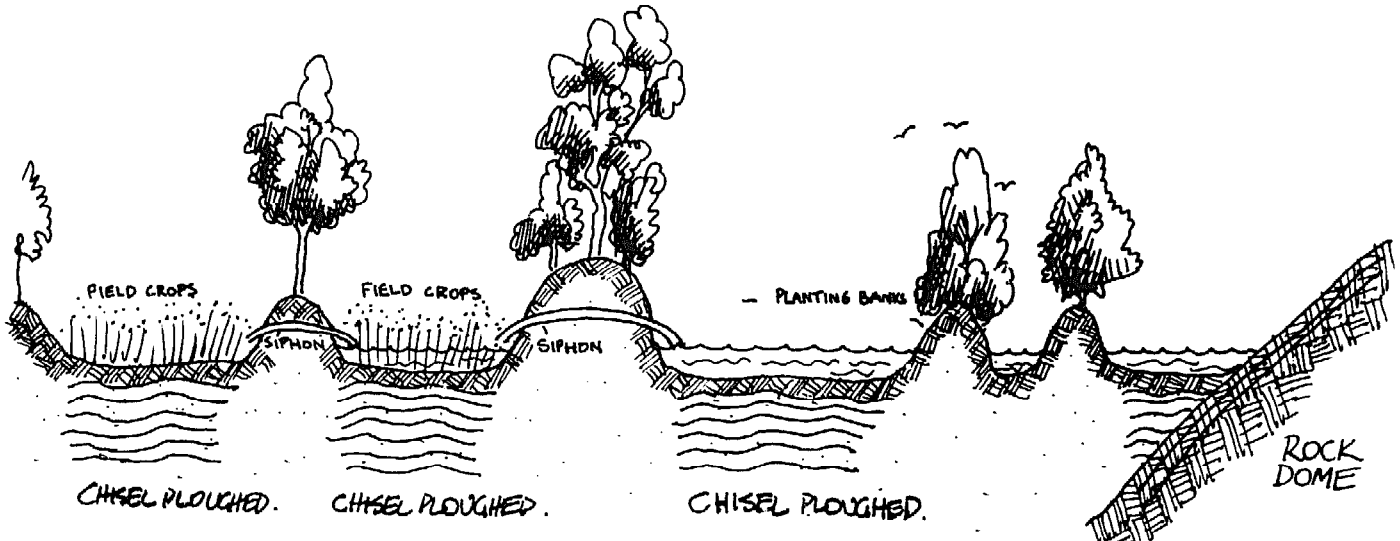
FIG.5·10: NEAR ERNABELLA.



OLD STOCKYARDS – DUNG ACTS AS UNDERGROUND WATER SPONGE. FIG. 5.11

RUN OFF OR LOCAL SELECTED SITE PLANTING

Clay pans, playa, domes, bare rocky ground and piedmont slopes can be graded to lead all run-off water to small, chisel-ploughed areas where permanent crop or gardens can be established. Already, existing roads provide one such resource. Allen Jenkins, of Papunya, suggests that the numerous graded road drains be led to walled and chiselled enclosures, or directly planted to trees, and new drains graded as these establish. At present, the drains themselves show an improved growth of trees. Road graders are available (if infrequently) to try out such techniques, and the plantings at Ernabella using Evanari's idea grow eucalypt and tamarisk at present. Automatic siphoning could be a feature of such impoundments, as rain is unpredictable. Again, small trials would suffice to test these methods (see Figs. 5.12 and 5.13).



SECTION AB OF FIG. 5.13 SHOWS SIPHONS AND FIELDS. FIG. 5.12

5.1

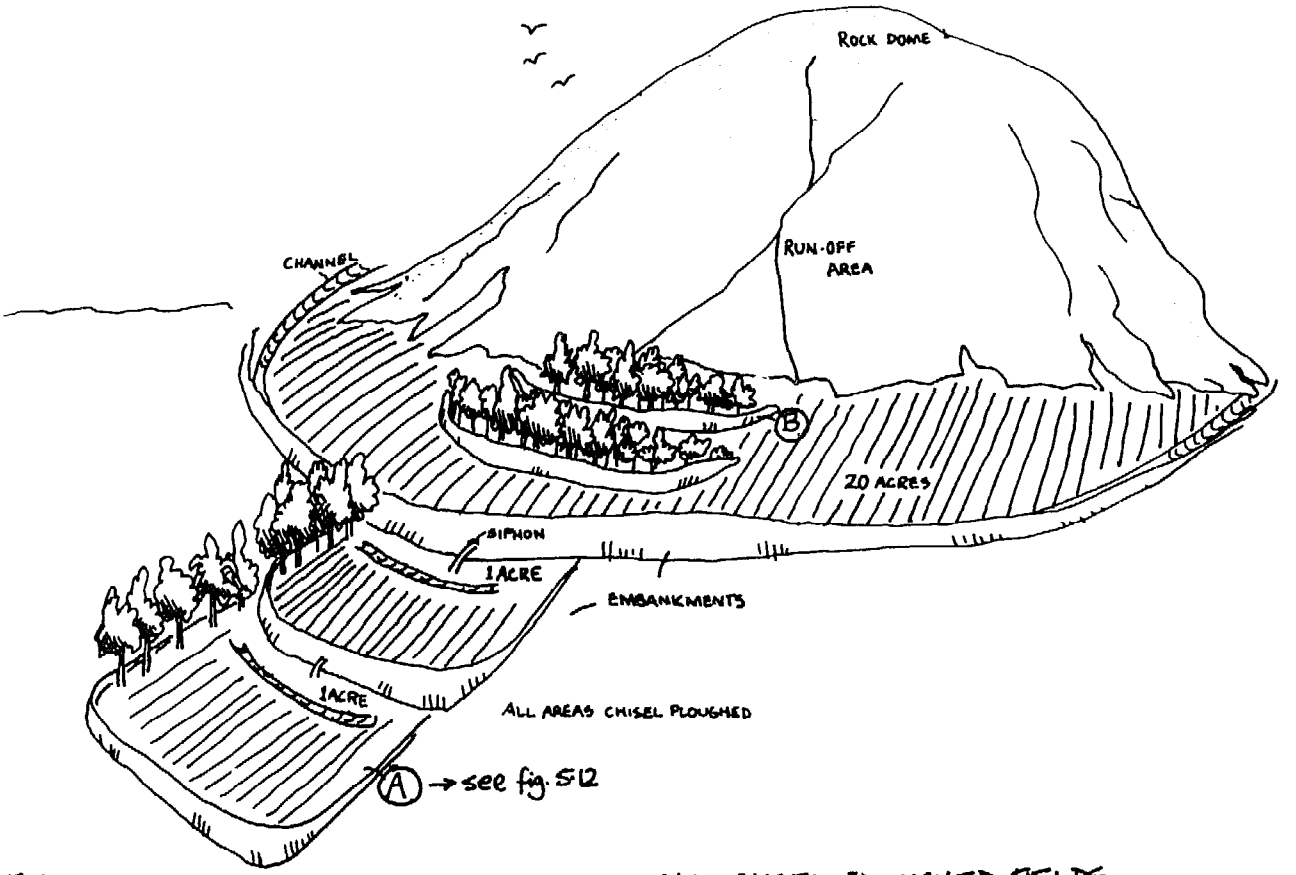


FIG. 5.13: RUN-OFF LED BY SIPHON TO SMALL CHISEL PLOUGHED FIELDS

Clay-pan, playa or dome led to small covered underground ramp tanks greatly assist the survival of useful quail, pigeon and poultry in arid lands, and fish can be used to keep them clear (see Fig. 5.14). The use of plastic sheet over holes, or mounds in salted water (see Maggs[27a], p. 120) are techniques which may serve small gardens or individual trees. Some very stony country (as at Ullumparu) present opportunities for rock-mulched garden on a larger scale, using 60-90 cm lines of gathered stone to mulch between plant rows (Fig. 5.17). Philip Gall (in conversation) says that Aborigines of West Australia use a modification of this technique to trap night moisture for drinking (see Fig. 5.19).

All of this needs time, machinery in establishment, and hard work, but the end result is a low-maintenance system, repairable by hand labour only.

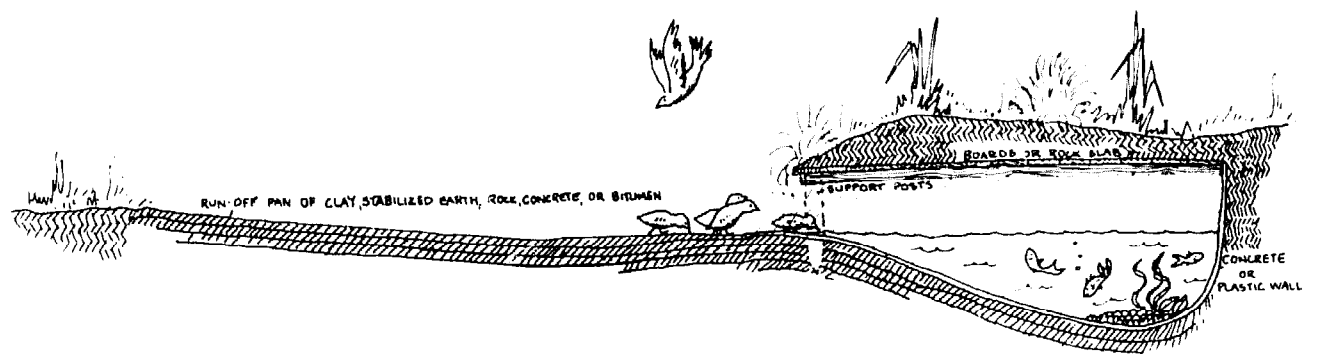
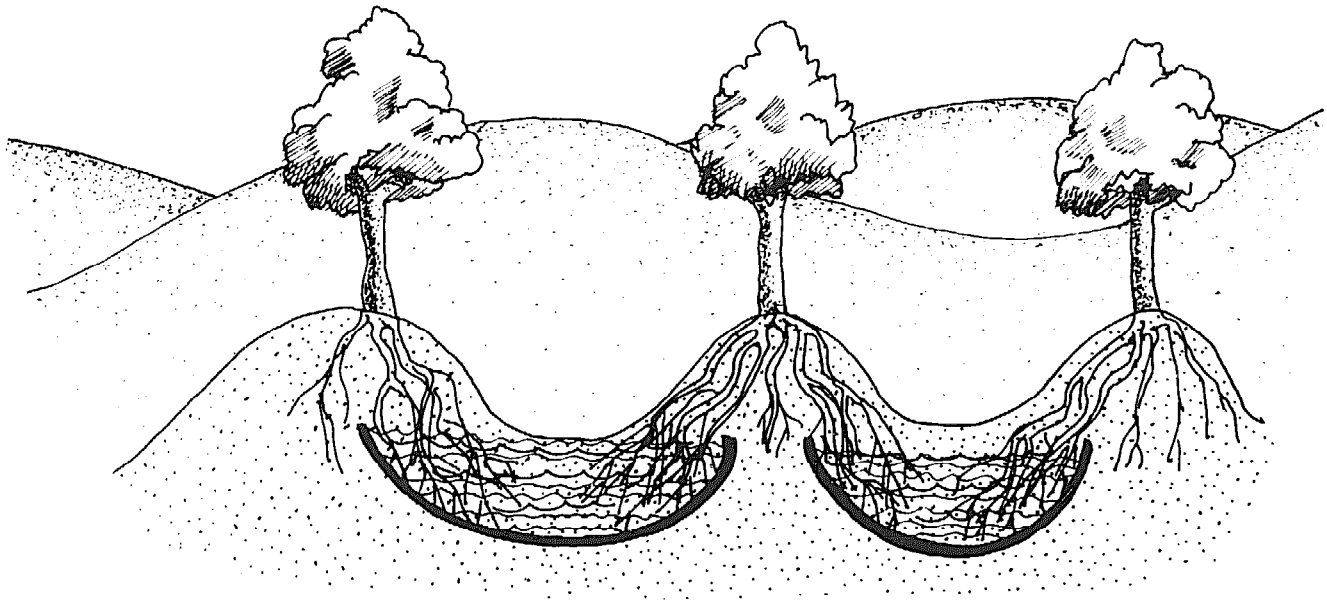
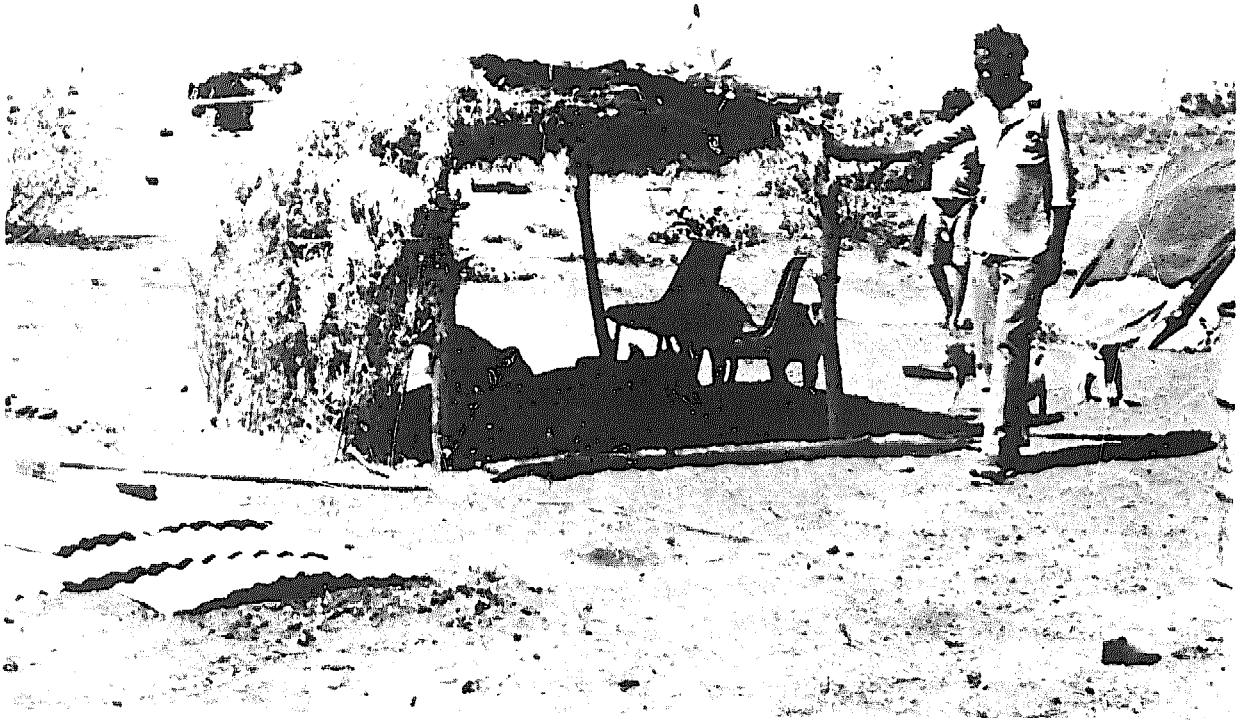


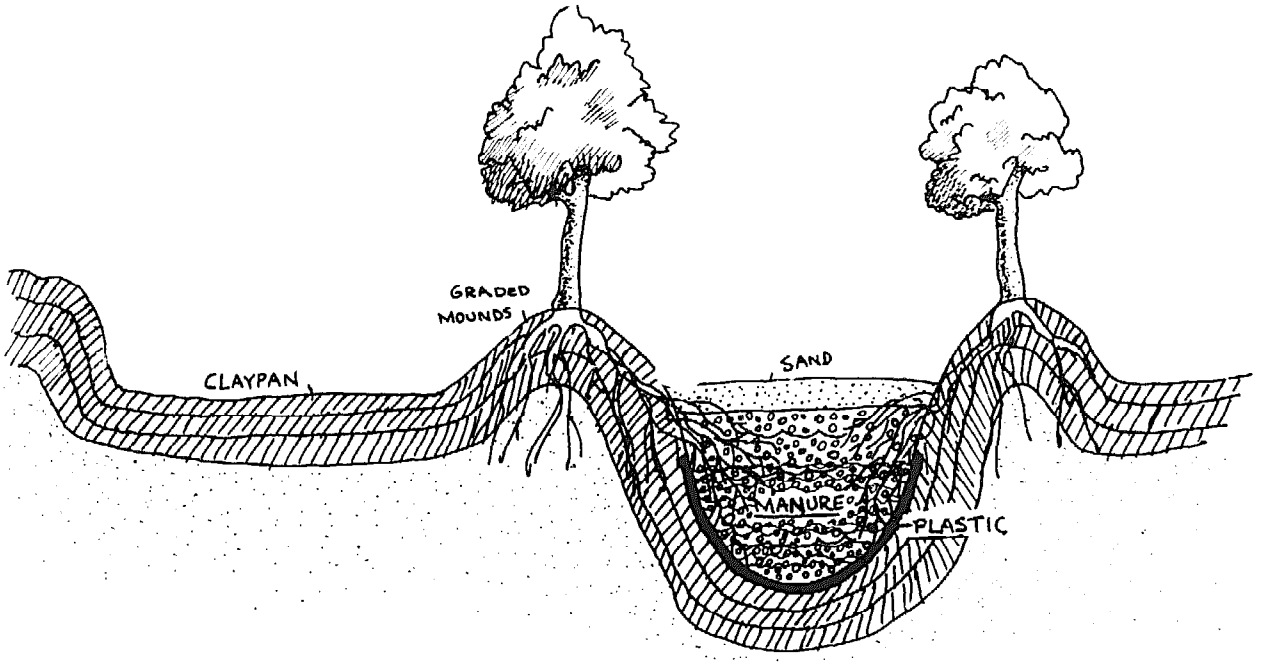
FIG. 5.14: SMALL WELL IN CLAYPAN OR ON ROCK BASE HOLDS WATER FOR QUAIL, PIGEON, LIZARD SPECIES, BEES. FISH AND MUSSELS KEEP WATER CLEAR. CATTLE CANNOT FOUL SUCH WELLS.



DUNES – SHEET PLASTIC 'WELLS' IN DUNES, OR UNDER BEDS HOLDS WATER FOR ROOTS. FIG. 5·15

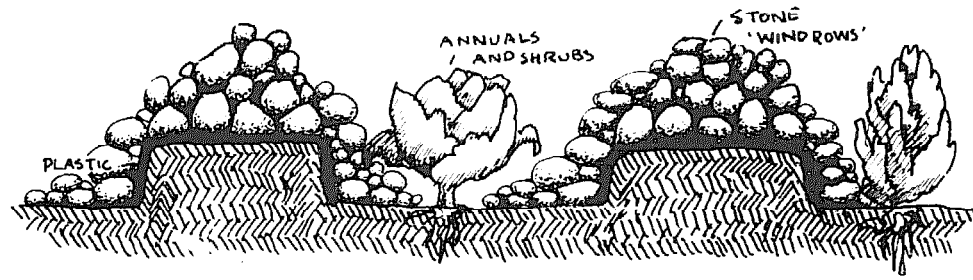


'YUU' AT KAAPA CITY OUTSTATION; 'WILUA' JUST VISIBLE AT RIGHT. PLATE 5·3
GROUND SWEPT CLEAN AROUND STRUCTURES, WHICH CAN BE OF GROWN PLANTS

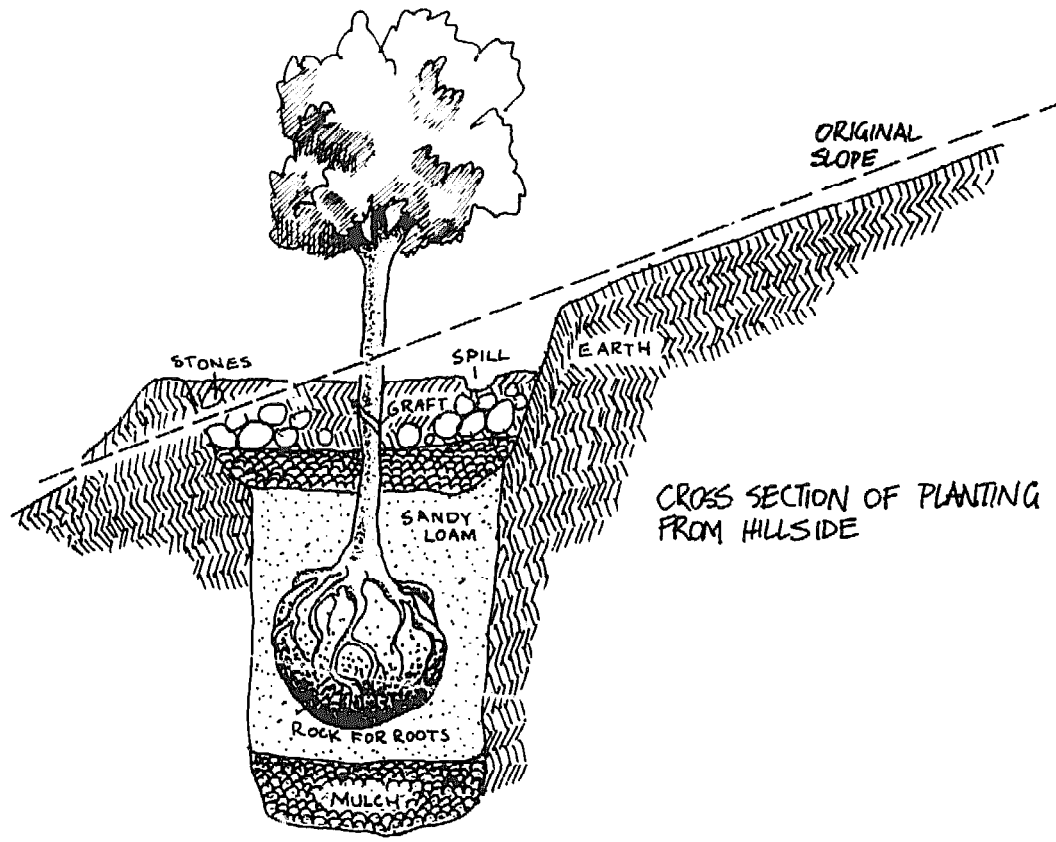


FIG·5·16: CLAYPANS — MANURE 'WELLS' IN CLAY PANS STORE FLOOD WATER FOR MOUNDED PLANTS.

PLATE 5·4: KIM AND ANDREW AT WOMIKUTTA, PLANTING OLIVE AND PISTACHIO AT THE FOOT OF A NATURAL GUTTER OF THE ROCK MOUND IN THE FOREGROUND. THIS DIPS STEEPLY INTO SAND (SEE FIG·5·7)

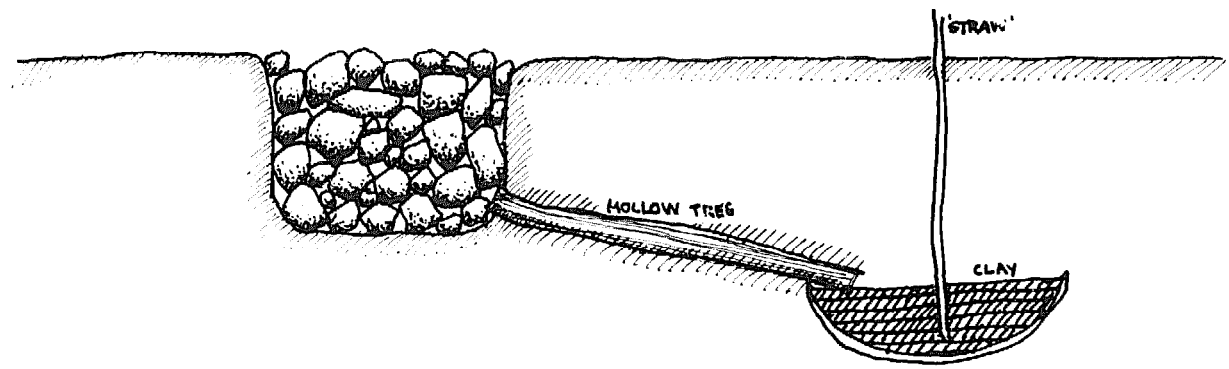


ULLUMPARA : VERY STONY PLAINS. FIG. 5·17



CROSS SECTION OF PLANTING HOLE FROM HILLSIDE

DETAIL OF PLANTING HOLE. FIG·5·18



NATIVE 'STILL' AS USED IN WESTERN AUSTRALIA (DATA FROM PHILIP GALL) FIG. 5·19:

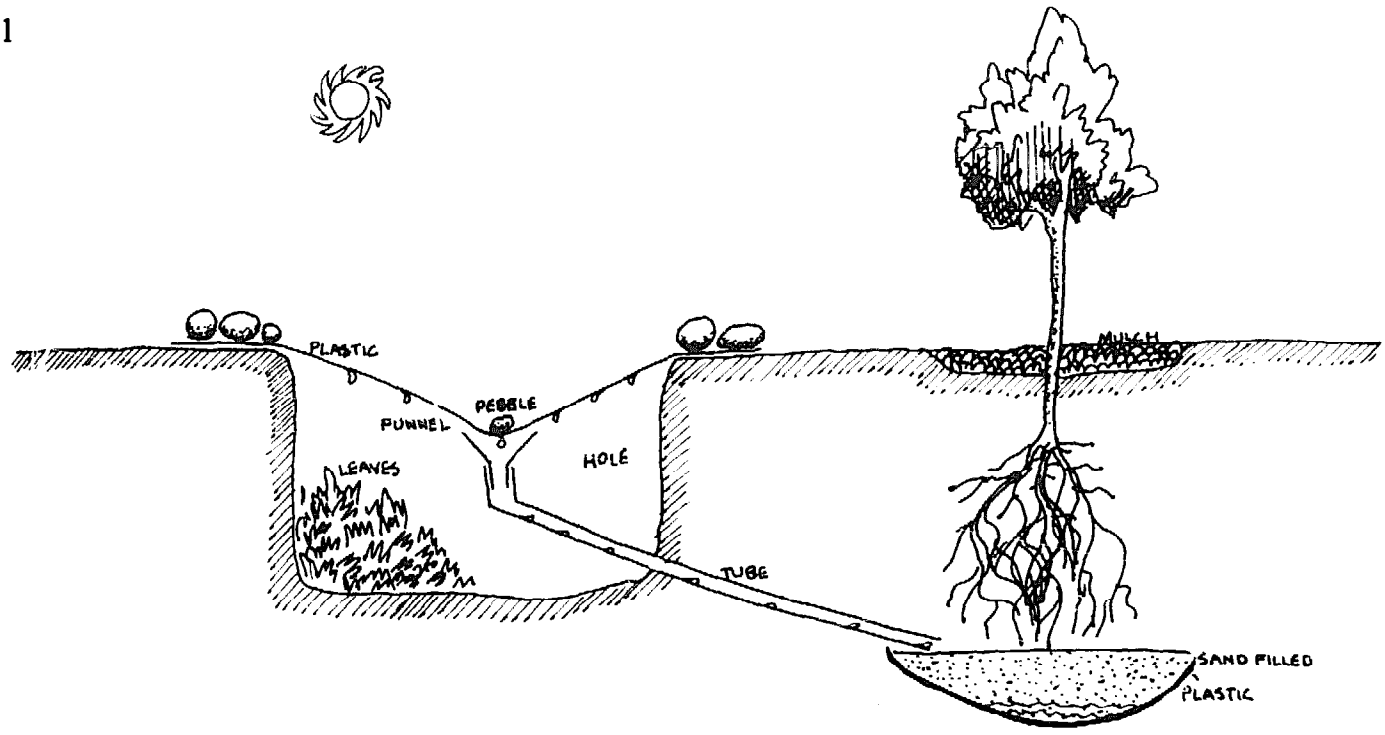


FIG.5:20: PLASTIC STILL USES LEAVES OR SOIL TO DISTILL WATER FOR PLANT RESEVOIR.

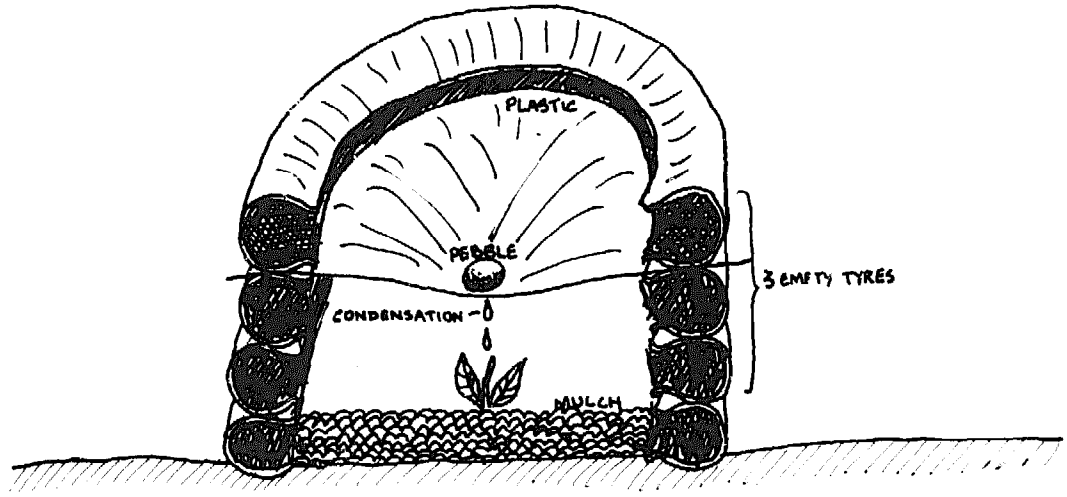


FIG.5:21: TYRE GLASSHOUSE — PLASTIC CONDENSES NIGHT MOISTURE. PLASTIC COVER REMOVED LATE SPRING. SELF WATERING AND FROST FREE.

2 · Livestock

FERAL HERBIVORES

At Ernabella, cattle and rabbits, and at Papunya brumbies and camels (fewer rabbits) make garden establishment difficult, while eating out traditional Aboriginal wild-food plants (60% are judged extinct, the rest greatly decreased). Damage to young trees and broken branches on old trees are obvious. Numbers of herbivores are very large—an estimated 6,000 cattle and 20-30,000 brumbies (wild horses) on Aboriginal outstation land, which supports only 1,700 or so humans! The animals, at present a disaster in that environment, could represent a potential cash resource if

ALLEN JENKINS AT ULLUMPARA DAM IN A ROCK-WALLED VALLEY. DAM PROVIDES AMPLE GARDEN WATER AT HEAD. MANY SUCH SITES ARE AVAILABLE IN DESERTS. PLATE 5·5

their utilization was properly funded, and planned by a group of people alloted to this problem alone.

Culling by cattle stations, who muster stock from Aboriginal lands, has left a lot of older bulls and cows. Many of these are of use only as sausage meat or pet food. After December, or in dry periods, the feral species are easily trapped on waterholes, using existing techniques of trap-yards and swing gates (Figs. 5.22 & 5.23). Other potential products are dried meats, hides, leather, horn, blood and bone and selected export camels for Saudi Arabia, or selected horses for southern markets.

Approved trailer-mounted processing units may be one answer, and market research is needed. (I may mention, as an aside, that Kew Gardens buries a horse each year at the base of an old grape vine, and harvests some 7 tons of grapes). But to poison or destroy all these animals is a waste of a potential cash resource and gainful employment.

Bulls and bull camels are a danger to people on foot, especially at night. Their fouling and breaking-down of river-bed and waterhole are obvious, and they prevent tree regrowth over immense areas of land. On dune country animal tracks cause bare sand to blow in wind. There is no doubt that smaller "softer" species such as poultry, wallaby, emu, and euro or kangaroo are to be preferred. Such small meats need no freezing as they can be eaten at one sitting, and cause little damage to the environment. The potential for utilization of feral species is obvious, but, again, needs personnel and funding to succeed. The whole question of feral species needs a separate team to resolve it. Automatic trapping at tanks and water holes has been perfected. The problems are transport or processing. Alternatives (distasteful) are mass burials in areas to be planted.

5.1 Foxes and feral cats are special problems. The rabbit (outside fences) is seen as an important food resource for nomadic peoples, and largely replaces small marsupial meats for families on outstations. Judicious regional poisoning in the early establishment phase of desert forests seems to be the answer for the rabbit. Ultimately, as suggested by Frith[27b] total destruction of feral species should be the aim. Their presence means a severe reduction in native species (animal and plant) and a reliance on domestic meats until the rangelands recover for emu, kangaroo, euro, wallaby, and regrowth of the native plants that were once the support of the nomadic tribes.

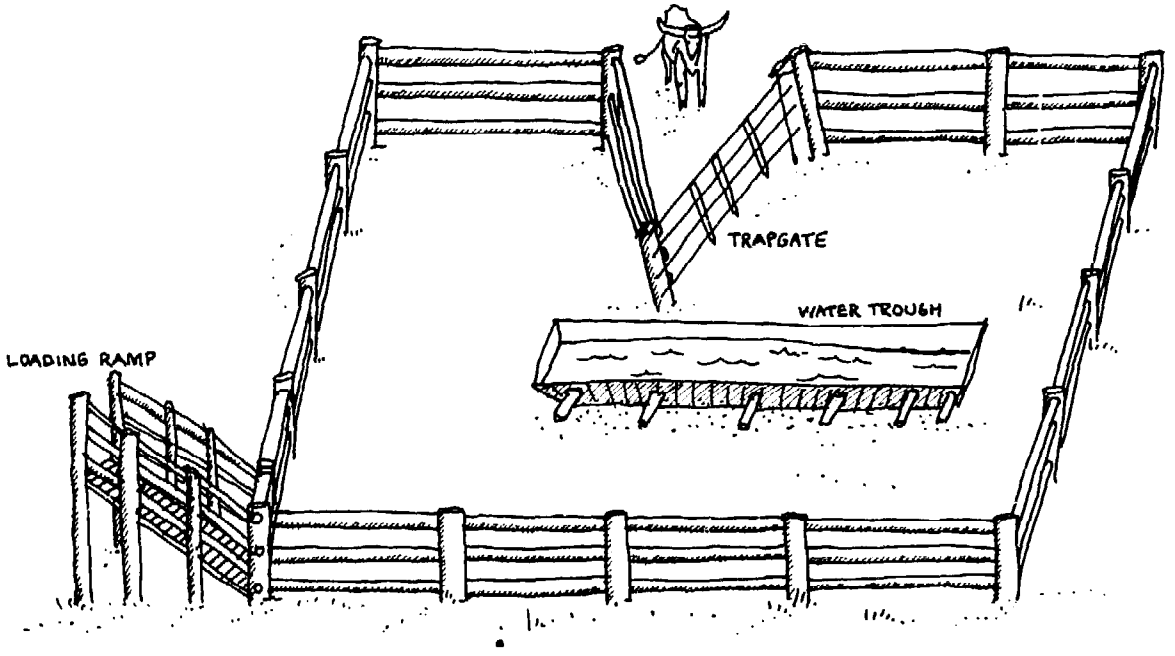


FIG. 5.22: TRAPYARD – WATER TROUGH ATTRACTS FERAL HERBIVORES IN DROUGHT.

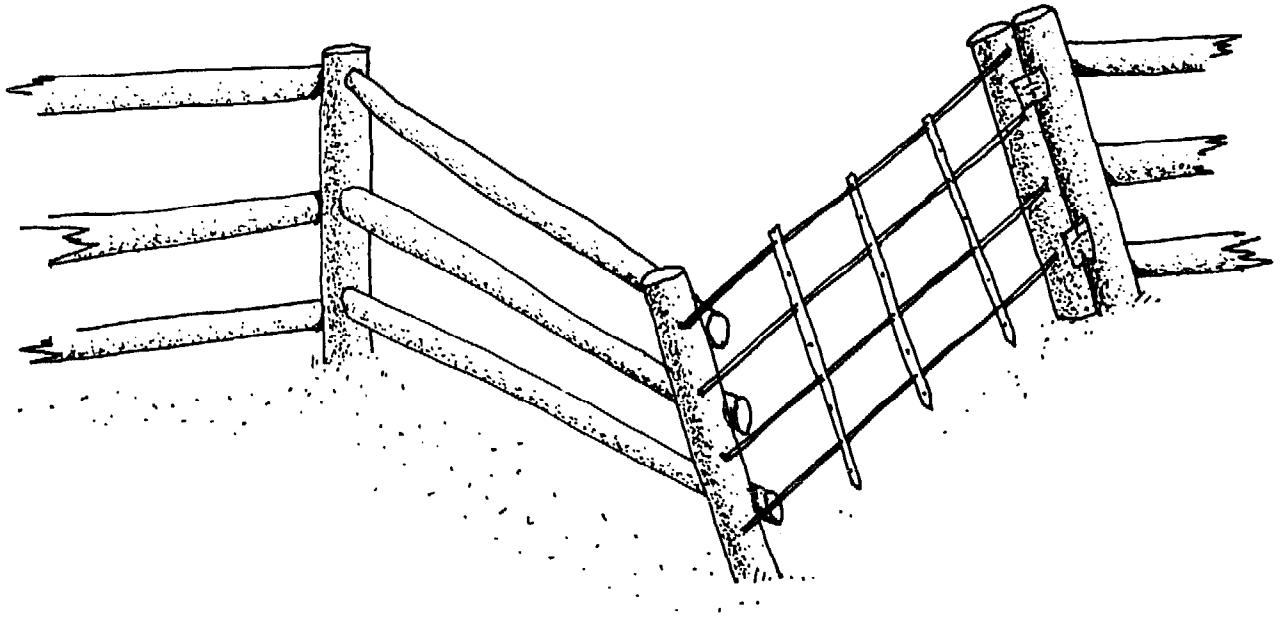


FIG. 5.23: TRAPYARD GATE DETAIL – SLANTED POSTS MAKE STEEL GATE FALL SHUT AFTER CATTLE AND BRUMBIES PUSH THEIR WAY TO WATER (SLANT EXAGGERATED HERE). AFTER TRAP AT WARREN'S CREEK.

WILLY AT ULUMPARA ABOVE SMALL DAM HE BUILT FOR HIS OUTSTATION GARDEN. PLATE 5·6

EXOTIC DOMESTIC SPECIES

Ducks and hens, their eggs and surplus breeders, would seem to be the main potential source of domestic protein. In tree crop areas, they also present opportunities for pest control (of ants, termites, snails) and are useful (as rakes) in fire control. Housed in insulated (spinifex) shelters on the south side of glasshouses (Fig. 8.3) they prevent night frosts in winter, by emission of body heat.

Guinea fowl and pigeons should be considered as prime candidates for camp food resources; the latter in traditional dovecotes, and the former as herded flocks. Both supply eggs, and meat. In mulga areas, a great deal of natural seed falls, and guinea fowl also utilize many insect foods and pests. On range, poultry may need elevated roosts and nest boxes (on pipes) to escape foxes and goannas. Pigeons in dovecotes are immune to fox predation (Fig. 5.24).

Fish have many uses, even, as mentioned previously, in the reduction of algae and mosquito larvae in tanks. Together with yabbies and mussels in dams, they also have some protein potential. Native fish species may be recommended by the Narrandera (NSW) hatchery, but in any case there is no risk of fish escapes *via* the desert and salt pans that buffer these areas from permanent streams. For this reason alone, deserts are an important trial site for water polyculture species.

Bees present an opportunity not only for honey but for pollen. Pollen traps (Ref. 28) are available now, and would supply high protein flour additives for outstations.

Native animal species:

The review by Frith [27b] is rather gloomy, and there is an obvious dearth of native Australian species at outstations. Some small reptiles (*Moloch horridus*, geckoes) may be of use in ant control and pest control in glasshouses, as would frogs (pools provided).

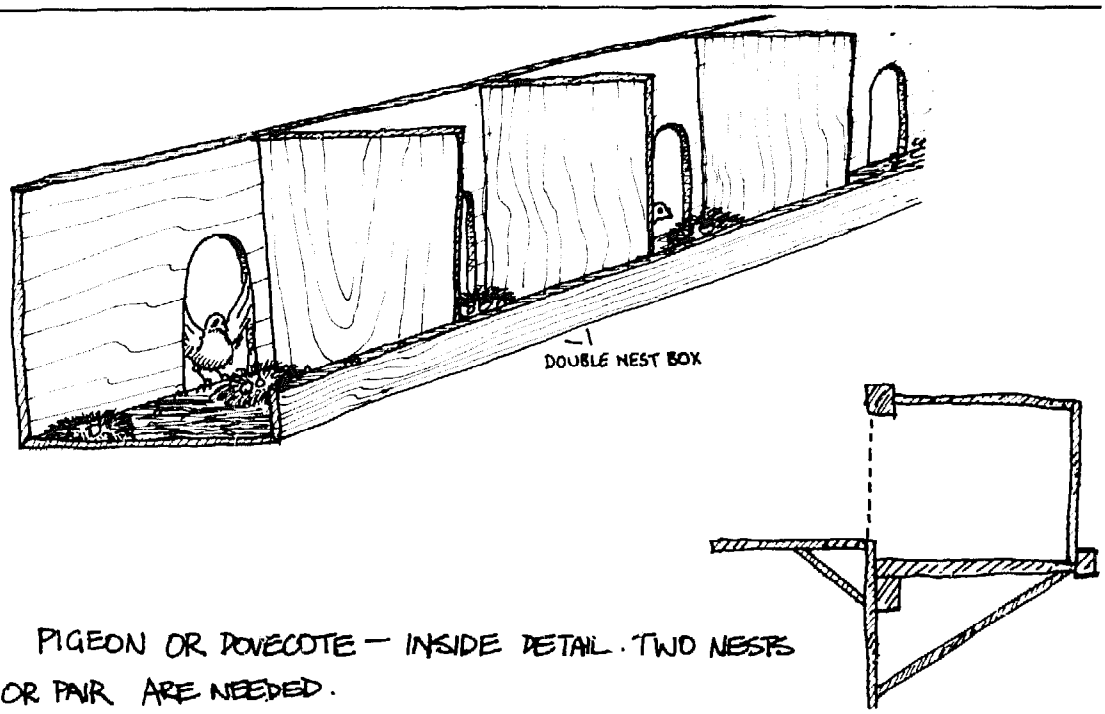


FIG. 5.24: PIGEON OR DOVECOTE — INSIDE DETAIL. TWO NESTS PER ENTRY OR PAIR ARE NEEDED.

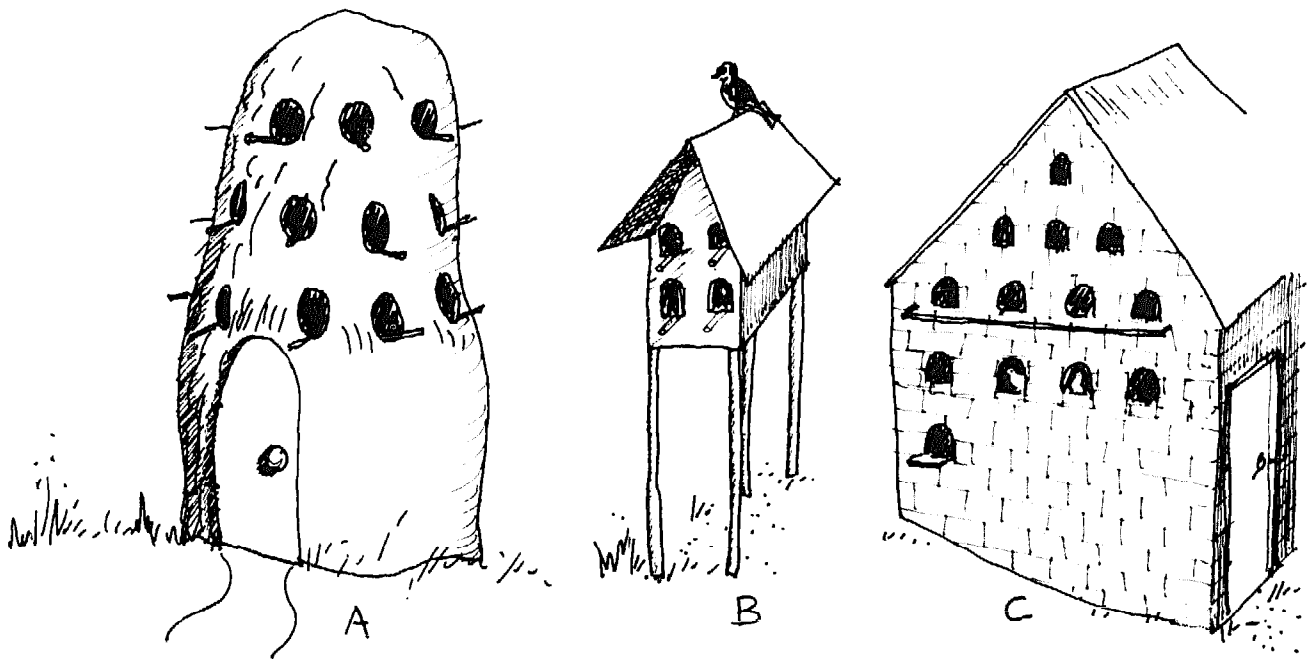


FIG. 5.25: DOVECOTES CAN BE OF DIVERSE MATERIALS: A MUD, B WOOD, C BRICK, NESTS CAN BE BOWLS, HOLLOWS, RINGS OR DEPRESSIONS ABOUT 230 MM ACROSS.

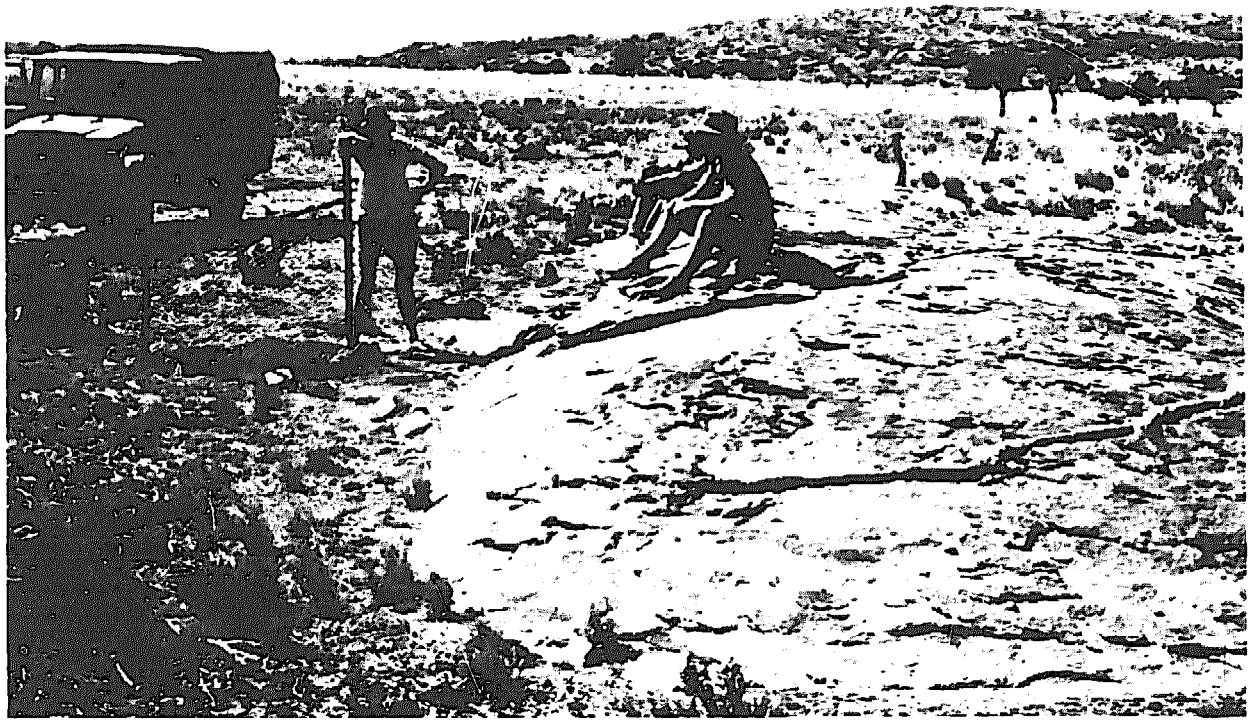
Shooting, particularly at night, kills many kangaroo rejected for food because of no fat or yellow fat. Baited compounds or traps at water holes make far more sense, as fat-free, female, and old male animals can be released to breed again, and only the immature and well-conditioned animals taken for food. I believe that active planting of emu berry, honey locust, tree lucerne and like forage may increase native animal numbers, but only if very selective trapping, not indiscriminate broadscale shooting, is envisaged. The real solution lies with the extermination of the feral ruminants, and with them, many of the flies that carry disease. Meanwhile, domestic exotics are needed at the outstations.

There are many areas, known to the Aborigines, where wallaby and rat-kangaroo survive. These could be nucleii for spreading harmless native species into the homelands if feral herbivores were controlled nearby. 5.1

Aboriginal Skills 3

In gathering seeds and small fruits, the Aborigine rakes clean the leaves from under selected trees, spreads skins or makes a funnel in sand, then beats the trees to bring down fruit or seed. By so doing, he has incidentally protected the tree from fire, provided a drip-line mulch, and thus altered the chance of survival of high-yielding trees. This is just another example of how, in his long history in Australia, the Aborigine has acted as a *de facto* agriculturalist. Gollan[10] records how they also stored seed in clay-lined pits, baskets, wood or stone hollows and transported seed over great distances, trying out such plants as native tobacco (*Mingkulpa*) at selected sites. Meats were dried, mussels stored in damp sand, and clay domes were made.

Mulching is no new thing either. Waterholes were thatched over to prevent evaporation, and it took only one demonstration with old blankets, cardboard, clothes and mulga or tamarisk "hay" to persuade Aboriginal gardeners that mulch was a good thing for water conservation. By mulching, the ashes, bones, and litter around camps are converted into rich garden soil, aided by water from showers, washing and kitchen preparation. The action of soil fungi, termite and bacteria in the heat of central Australia, quickly reduces potentially noxious wastes to soil, hence to a food resource.



WOMIKUTTA. SMALL DOME FITTED WITH A CONCRETE GUTTER BY ANDREW AND KIM LEADS TO A NETTED TREE ENCLOSURE WITH PISTACHIO. (SEE FIG. 5.5). GUTTER IS SNAKE-LIKE LINE ON STONE. PLATE 5.7

5.1 It has been traditional for the Aboriginal children, and adults, to break off mulga twigs and branches to gather mistletoe berries, scale-insect sugars, and edible galls. Some effort must be made to show correct methods of harvesting introduced fruits such as grapes, oranges, and small-fruit to people unused to picking the fruit, rather than the tree.

Sophisticated tracking skills are evident, as is skill in food preparation. A very large (and largely unrecorded) vocabulary exists, detailing food plants, fire effects and control, the links between species, and general ecological patterning. Combined efforts by linguists, botanists, astronomers, ecologists, and generalists are needed to recover the detailed information of the older people of the deserts, and to record the uses of plants for food and medicines.

This is very worthwhile on medical grounds alone, but more so for the potential value of native plant species in arid lands generally, or for their use in areas where tribal knowledge has been lost.

4 Permanent Grain Plots

Aside from garden and orchard, the rehabilitation of natural foods, and enclosures, there are other techniques applicable to arid lands. Perpetual grain plots, unploughed, can yield about 11,750 kg of grain per hectare (10,500 lb/acre), plus legume seed. Such a system would be ideally sited under vine crop or *Paulownia:* small trials of about 400 m² (1/10 acre) are needed.

Using the CSIRO "ripple-flow" process, all grains, sunflower and legumes can be hulled and ground to flour in one machine. This machine needs a 16 h.p. (tractor) motor, and hulls or grinds 4-5 tonnes of grain per hour, so is suited to central processing in small settlements and communities. Purchase price at $4,500.00 means many people must use one machine, although a similar but smaller model may be developed in the future. Trials on native seeds such as mulga would be useful.

5 Poultry Forage systems

It is very probable, with the many useful acacia species present in arid areas, that a successful forage system could be quickly evolved. Some poultry forage species are suggested below:
Sunflower: Does well everywhere. Heads can be cut off and fed entire to poultry. Resists fire. A trellis for lab-lab and pole bean crop. A good short-term windbreak, provides some mulch. Almost wild at Alice Springs, Papunya, Ernabella. Husked, it provides good oil and food for humans. Deserves broadscale trials as a 'grain' crop. Unopened heads can be eaten as a vegetable.
Millets: Sorghum, sweet corn, sudax. As above. Sudax as a mulch/border species, sorghum for sugar, seed. All can be used as human food or forage.

NATIVE SEEDS AND BERRIES

Panicum decompositum (Native millet or Kalta kalta)
Eragrostis eriopoda (Wangana)
Portulaca oleracea (Wakati)
Themeda australia (Kangaroo grass)
Owenia reticulata (Emu berry, Marloo, Gnarloopoo)
Chenopodium rhadinostachyum
Paspalidum jubiflorum
Acacia aneura (Mulga, Wata or Kuraku)
A. kempeana (also for witchetty grubs)
A. boloserica
A. cowleana
A. victoriae
A. binervata

A. longifolia
A. peuce
A. oswaldia
(all of the above have been used as food plants for man with the exception of Emu Berry (*Owenia*) eaten by emu and crested pigeon).
Acacia sp. (mungona): and many species of large-seeded edible berries, including those of the mulga mistletoe (*Ngantja*) and a black-berried evergreen (*Awaluru*); poultry would also utilize the nut-grass (*Yalga*)

Add to these, the exotics:
Tree lucerne (*Chaemocytisus proliferus*)
Black locust (*Robinia pseudoacacia*)
Honey locust (*Gleditsia triacanthos*) (also for pole timbers)
Banana passionfruit (*Passiflora mollisima*) (Stands frost)
Mesquites (*Prosopis* spp.)
Comfrey
Olive (also for oil)
Lespedeza
Lucerne (also for sprouts, green forage)
Mulberry—a first-class poultry fodder, esp. white mulberry
Chinquapin oak (*Quercus muhlenbergii*) (sweet acorn)
Holm oak (*Q. ilex,* evergreen)
Cork oak (*Q. suber*—also for cork)
Chestnut oak (*Q. prinus*)
Plus any of the desert oaks obtainable. All acorns are good fodder for storage. Some are sweet to eat. *Acacia albida* (see Ref.17) could also be of use.

The CSIRO, Division of Plant Industry, Canberra have seed of a *perennial* rye and millet, well worth forage trials.

If an area of mulga were fenced and selected breeds of poultry tried out (with guinea fowl and pigeon), the foregoing species would provide the bulk, if not all, of the fodder. Most species could be introduced with mulga as the cover crop, and other less useful species gradually eliminated. Close observation would give a lot more data on a free-range poultry system for arid areas.

Surprisingly, ducks do well at Ernabella, but need special protection from dogs, foxes, etc. Grain could be fed in early stages, and lab-lab beans tried for greens and ground cover, in 'alternating' pens.

Poultry on range in mixed orchards greatly reduce the larvae of insect pests, especially fruit fly and termites.

AQUATIC SPECIES

As dams, tanks and lagoons are developed, more attention should be given to aquatics. Gollan[29] mentions a native wild rice, and the multiple uses of the water lily *Nymphea gigantea* (stalks, tubers, seeds). Nardoo (a fern) is also an aquatic, as is native arrowroot. *Trapa* or *Eleocharis* (water chestnuts) do well in this climate in S.W. Asia, as does Lotus. Sweet rush (present, I think, at Ernabella) provides shoots and bulbs. *Trapa* should reduce summer evaporation from open tanks or dams.

Notes on Aboriginal Nutrition 6

Dr Archie Kalikorinus of the Aboriginal Medical Centre in Sydney agrees that improving nutrition and hygiene at camps and in outstations would be "better than all the medical services" for health (in conversation). High vitamin C content in fruit, especially for women before and during

5.1 pregnancy, is a prime aim. This is a good reason for involving women directly in the gardens. Plants he recommends, which are possible to grow above frost level on slopes, are paw-paw, mango, tomato, peppers. In addition, *acerola* (Barbados cherry) parsley, and any green leaf crop are also of value. Field testing of Vit. C. content of fruit juices is cheap and easy using the "C" sticks developed by the Ames Co. This is a simple 'dip' indicator used to measure vitamin C content in mothers milk, urine, and plant juices. Both milk and urine should show high levels of excretion. Fresh fruit needing minimal care (no artificial fertilizers, sprays, or forcing) is best for vitamin C content. Advisors and camp gardeners could test the success of their crops and check on the urine of mothers and children, or teach them how to do this for themselves. The same tests should be applied to native species, store "foods" and fruit juices supplied or bought on outstations.

Some investigation could be made (if it has not already) on the effects of clothing on Vit. D synthesis, hence rickets in children. The publication "*Modern Urine Chemistry*" (Ames and Co. 1976) is available from the Miles Laboratories, 13, Spring St., Chatswood, NSW 2067, and may be helpful in outstation health analyses.

7 Annotated List of Useful Arid Land Perennials

(See also Refs. 17, 25, 26, 28, 29, 30)
Est. = already noted as thriving in arid Australia.

EXOTICS

MULBERRY (*Morus* spp.).	Est. only red or black varieties. Could add white mulberry. Poultry forage, high vitamin C, fruit can be ground to flour. Hardy, resists white ant, fire.
CAROB (*Ceratonia siliqua*).	Est. Attacked by termites. Needs careful site selection, also needs 5% male trees in stands. High nutrient value for forage, people.
CITRUS *spp.*	Est. are oranges, lemons. Needed are limes, grapefruit, other citrus spp. High vitamin C value. May need *Tagetes* understorey to control eel-worm.
BLACK LOCUST (*Robinia pseudoacacia*).	Very durable timber and useful poultry seed, but spiny leaves are toxic to stock in large quantities. Non-inflammable bark and foliage, hardy. The toxic quality may be advantageous in many areas.
HONEY LOCUST (*Gleditzia triacanthos*)	As above. Leaves not poisonous, edible beans.
OLIVE (*Olea europea*)	Est. Useful oil crop and shade tree, easily propagated from cuttings. Good poultry forage crop. Many species possible. Dates est. at various centres. Queen palm, bobassus, oil palm etc. need trials. Hardy and useful plants along watercourses. Coconut possible.
FIG (*Ficus spp.*)	Needs more varieties for trials, and possible hybrids with native figs.
MANGO (*Mangifera indica*).	Est. at Mt. Isa. Could be more widely grown in many areas.
CASHEW NUT (*Anacardium occidentale*)	Est. but needs wider trials.
INDIAN OIL NUT (*Calophyllum inophyllum*)	Est. Characteristics not known.

CACTI	Several selected fruiting species need wider trials. Useful hedgerow and non-irrigated crop species are available.
PISTACHIA (*P. vera*)	As for other untried species. Seedlings survive well.
SWEET CHESTNUT (*Castanea sativa*)	As above. Should succeed in frosty areas, along stream beds.
ALMOND (*Prunus dulcis*)	As above.
PLUMS (*Prunus spp.*).	As above. Many varieties are established but need wider trials, especially prunes and gages.
JUJUBE (*Zizyphus jujub*).	Est. Needs wider trials as hedge.
POMEGRANATE	Est. as seedlings. Should be a major summer fruit, Pakistani spp. keep well into winter.
CHERRIES (*Prunus* spp.)	As above. Near watercourses.
GUAVA (*Guavaja, Pisidium, Myrtus*).	True guava, feijoa, strawberry guava and ugni would all do well in sheltered areas. *Pisidium* is est.
PASSIONFRUIT (*Passiflore mollisima*).	Banana passionfruit. Stands frost, good poultry fodder.
STONE OR NUT PINES (*Pinus, Auracaria*). *P. coulteri* *P. pinaster* *P. pinea* *A. bidwilli*	Several species. Also the pinon of Mexico, other desert nut pines. Some est.
KARREEBOOM (*Rhus lancea*)	South African. Est. Frost resistant, termite resistant. Fodder, small edible berries are food for poultry.
PAW PAW	Worth trials in small selected areas.
GRAPE	Est. Many cultivars do well. Some 26 varieties flourish.
VINECROP GENERALLY	Kudzu, hops, kiwi fruit and other vine crop would help with shade and forage.
CAPE GOOSEBERRY	With native tomato, kangaroo apple, tamarillo and like *Solanum spp.*, worth trials and hybrid trials or grafts to native stock. High vitamin C. Capsicum and egg-plant should be perennial above frost line. Many of these species est. Some very useful perennial species are local in use but need selection and cultivation.

LEGUMES FOR INTERPLANTING:

Centrosemia pubescens	Est. Brings up moisture to topsoil (Yeomans, in conversation).
Paulownia spp.	As above. Aids in providing surface moisture.

5.1

Leucaena.	As above. For frost-free areas.
TREE LUCERNE (*Chaemocytisus proliferus*)	Fire and frost resistant. Stock and poultry fodder.
MULGA (*Acacia aneura*)	And several native acacias, as previously listed.
Acacia albida (Africa)	"Wet deciduous" in monsoon. Hardy, poultry fodder.
Mesquites.	

HEDGEROW

Coprosma repens	And other N.Z. species of Coprosma. Resist fire; poultry and stock fodder.
Bamboo spp.	Est. Larger black and giant bamboo needed. Very useful for structural needs.

Cacti, Wormwood, Jujube etc.

SHADE AND SHELTER ONLY

WHITE CEDAR (*Melia azerdarach*)	Fruits poisonous to pigs and poultry. To be used with care at settlements, as for oleander.
JACARANDA (*J. mimosifolia*).	
TAMARIND (*Tamarindus indica*)	Marginal food use.
TAMARISK (*Tamarix articulata*)	Also for mulch.

USEFUL NATIVE SPECIES (a restricted list)
(See also section on poultry)

KURRAJONG (*Brachychiton gregorii*)	Nectar, pollen, fodder, bark fibre.
BOTTLE TREE (*Apophyllum anomalum*)	Fodder, possible spice.
EBONY (*Bauhinia carronii*)	Leaves and pods edible stock food.
LIME BUSH (*Eremocitrus glauca*)	Small preserving fruit, grafts.
NATIVE CURRANT (*Canthium latifolium*)	Fruit and fodder, poultry.

WILD ORANGES (*Capparis mitchelli, C. ambonata*)	Fruit eaten by Aborigines.	5.1
BERRIGAN (*Eremophila longifolia*)	Emu and pigeon food.	
FIG (*ili*) (*Ficus platypoda*)	Fruit and graft stock for cultivars.	
EMU APPLE (*Owenia acidula*)	Edible fruit, emu forage.	

Vegetables

A. Perennial

Globe artichoke, asparagus, sweet potato, (*Dioscorus*), Manioc (Manihot), comfrey, beans. *Herbs:* Chives, potherbs (sage, thyme, marjoram, mints)

Many perennial onions not tried as yet.

B. Biennial

Parsley, fennel, like umbelliferous spp. Some established. Celery.

C. Annual

Sweet corn, tomato, melons, borage, lettuce, chard, spinach, sprouts, cabbage, peas, beans.

D. Tubers and Roots

Potato, sweet potato, turnip, carrot, onion, manioc, jerusalem artichoke, oca. Also native wapiti and yala.

Acknowledgements and Apologia 8

It is very pleasant to sit here, in cool and green Tasmania, nursing my tropical ulcers, and make bright suggestions. My admiration for the men like Mike Last and Ken Hansen, who spend years at their work in pretty awful conditions is unbounded.

As often as not, dedicated people are as much impeded by whites who are exploitive, or by paper work, as by the task ahead. Young people who go to the centre see how necessary it is to stick to the job for years before results appear.

My admiration for the intelligence and endurance of the Aboriginal people is also great. They know many things we need to know, about meaning in life, and about their country's ecology. They will be successful again, despite the messes we have made for them.

I am very grateful to Charlie McMahon, and Mike Last for organizing the trip; to Charlie, Andrew Prior, Mike, Allen Jenkins, Kim Tjitaya, Ginger Wikilyiri, Willy, and John Kantawara for data on plants, techniques, native species and for transport and assistance; and to Rosemary, Wendy, Jane and Jill for hospitality and cups of tea.

It seems clear to me, even today, that the eventual inheritors of the arid regions will be (almost solely) Aborigines: that we have a long-term outlook to take, and that Aboriginal people will slowly become masters of their own lands in this area of Australia. We can impede or assist this process, but not halt it. As a people, they are (when fit and well) active, intelligent, marvellously adapted to their environment, quick to learn, and capable of every sort of craft and technical task. We block them by demanding literacy in our terms, by denying their culture, and by continued racism.

Sadly, there is too much evidence of ill-health in adults and children, and too little action. We persist in erecting institutions to deal with what is basically a domestic situation. We lack 'barefoot doctors' and 'barefoot gardeners', especially the latter, who strike at causes rather than

5.1 effects. Millions are wasted on sophisticated buildings which don't work and give nothing to thoughtful design. White employees, chosen by the government, are at times outright racists, 'in it for the money'. A cynic would say that we intend to perpetuate the misery of a people, in order to sustain the "Aboriginal industry". Like Dr Duguid, I feel very angry and betrayed by my own race, in their lack of action, good-will, and involvement, and by the attitudes of some public servants.

The world will judge white Australia in the light of results, not intentions. Good intentions are not enough. We must listen to the Aborigine, and by so doing will gain much ourselves, or take the path of the Rhodesians and South Africans. The contrast between the non-productive, Pine Gap military expenditure and the misery of people around it is glaring. It was the same in Iran, and the turmoil there reflects the effects of senseless repression and the maintenance of 'haves and have-nots'.

PLATE 5·8: AUTHOR ADMIRES THE HARDY NATIVE FIG (*FICUS*), SURVIVING IN THE MOST ARID AND ROCKY SITES. IT CAN BE USED AS ROOT STOCK, TRELLIS, SHADE OR NURSE TREE.

Poulsen[17] greatly reinforces the thesis of *Permaculture One,* where we called attention to the "nutrient pump" role of trees. Both leaves and roots trap minerals from air and weathered stone, and the leaves recycle to topsoil. *Prosopis cineria,* he says, penetrate to 30 m, *Acacia tortilis* spreads a root net 40-50 m, so that planting relatively few of these efficient root nets ensures a large safety web under gardens.

In drier regions, this same author recommends *A. albida,* a unique species which is deciduous in the wet season, and so does not shade crops when rain falls, but protects from clear sunny skies. He also has praise for "zero tillage farming" in tropics by way of branch mulch from *Prosopis, Acacia,* and *Ailanthus excelsa* used as hedgerow, windbreak, and fodder crop for sheep. Farmers in Rajasthan (India) "maintain as many as 40 *Prosopis cineraria* per hectare, and the nutrients are detoured through livestock as an ideal way of using branch mulch."

Poulsen illustrates how cotton grows under shea butter trees, while Van der Muelen recommends lab-lab (*Dolichos*) beans under *Bobassus* palm. Frank Martin and Ruth Roberte of the Mayaguez Institute of Tropical Agriculture (Puerto Rico) have printed yet another of their excellent guides to survival and subsistence in the tropics. They also develop a plan for an excellent little round garden of essential crops, paying great attention to nutrition. Their books are basic manuals of knowledge and skills, with reference to almost every aspect of tropical survival *via* plant and animals. Figured here is the excellent *Samaka Guide to Homesite Farming* of the Phillipines.

It is also on the edge of the monsoon area where Fukuoka[3] has developed his remarkable no-dig system of growing, using only poultry as manurial sources (ducks are good pest controllers as well as recyclers). So it is not for lack of strategies that we do not have a stable tropical system evolved, just that we need people to put the strategies together and practice them.

As well as strategies, species and layouts, the essential design for wind, sun, and human comfort is also needed. In the humid tropics, the shadehouse of temperate zones may need *dry* mulch to de-humidify air as it is drawn into the house, and there may need to be defences on *both* sides of the house, as the sun traverses from tropic to tropic. Compensations are the vast range of useful fruits and year-round production of crops.

Humid Tropics 1

It is in this climate that I, like many Europeans, do not thrive, and it is difficult to sort out the riot of species and combinations. Here, almost all nutrients are mobile, and contained in the web of life. The soil is fragile, easily leached, often very deeply rotted, and converts quickly to laterite or erosion gullies if cleared. If ever tree crops had a place, this is it. Trees grow easily from seed and cuttings, divisions and roots. Some trees are necessary at all times, even over crop. Poulsen[17] asserts that "more than 75% of the soluble plant nutrients that are present in a certain area are held within the biomass of the growing plant comunity". These nutrients, he says, are not absorbed into the soil, as in temperate climates, but are caught in the web of roots and fungal symbionts below the soil surface. Only 'transitory' fertility is released by clear-felling, then the leaching of nutrients, and sterility of soil results.

Poulsen's small pamphlet is a manual of condensed strategy for humid tropics. Converted into diagrams or schematic figures, his and Van der Muelen's lesson is clear. We must maintain high biomass by mixed perennial/tree/crop species in wet tropics.

Even in this climate, the winds that blow outside the rainy or monsoon seasons are very arid and damaging, carrying the breath of the desert into gardens. Thus, the same windbreak and forage strategies that apply to temperate and arid lands still apply. Mulch is as much, or more important, and has more manurial value, and animals of all sizes help keep the energy on the move and are useful as harvesters of scattered nutrients.

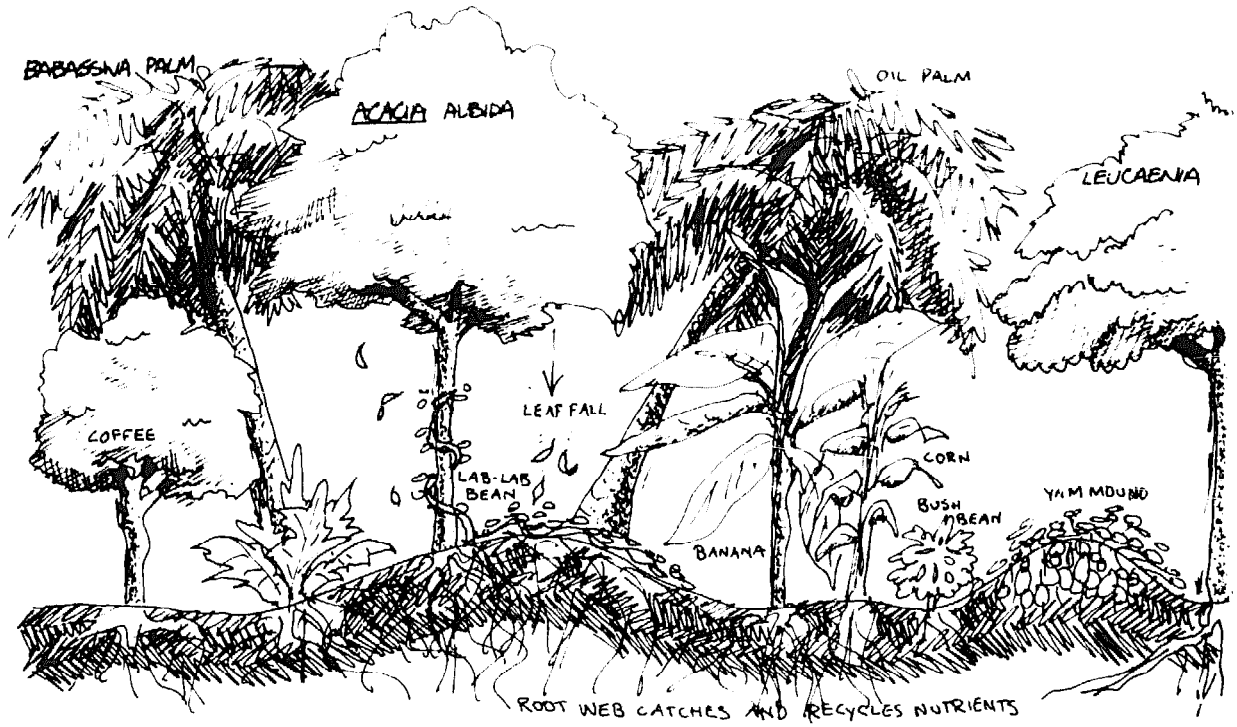


FIG. 5.26: TROPICAL STRATEGIES OF PLANT STACKING AND NUTRIENT RECYCLING. CROPS ARE MULCHED FROM LEAVES AND BRANCHES OF TREES, WHICH HOLD THE LEACHED NUTRIENTS IN AN UNDERGROUND ROOT WEB.

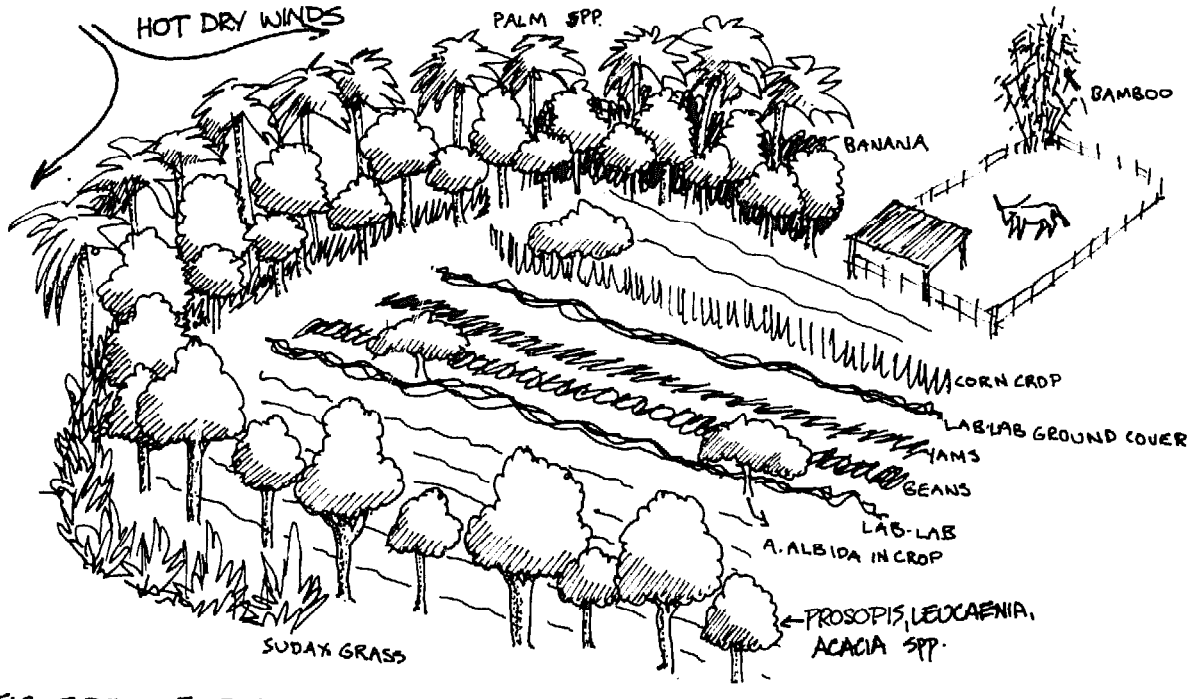
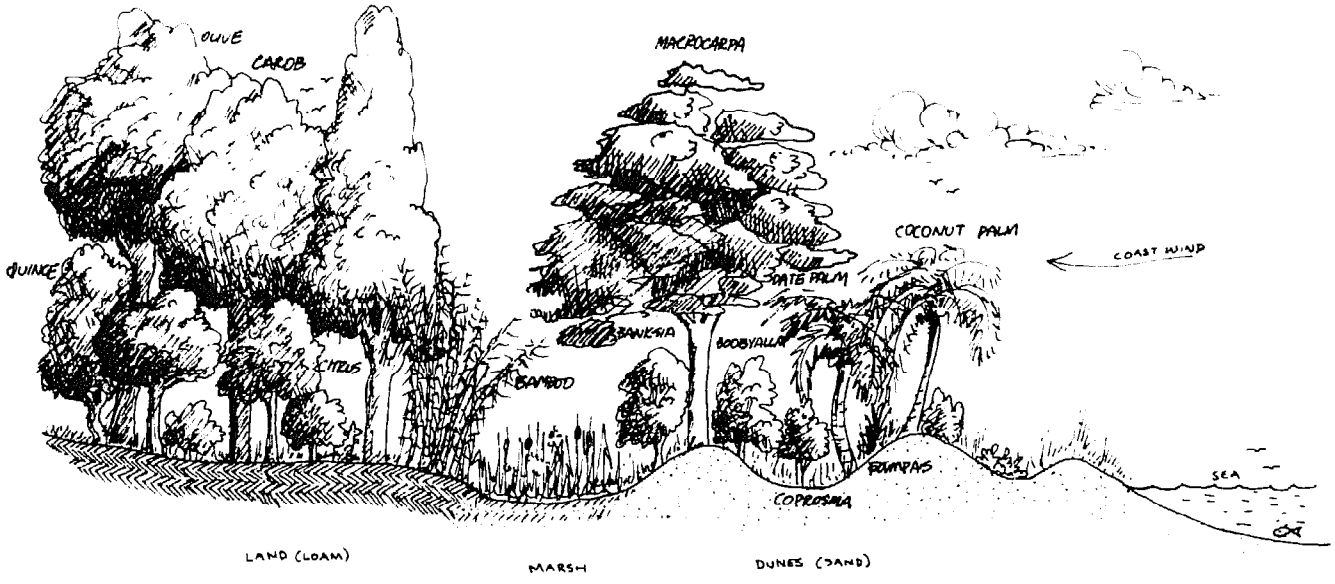


FIG. 5.27: TROPICAL STRATEGIES FOR NUTRIENT RECYCLING — BRANCHES AND LEAVES FED TO LIVESTOCK ARE RETURNED TO FIELD CROP, PROTECTED BY HEDGE-ROW AND SEED PLANTS WHICH ARE FED TO POULTRY AND CATTLE. MANURES ARE RETURNED TO FIELDS WHERE LEGUMES AND PULSES FORM GROUND COVER IN ROOT AND GRAIN CROPS. TREES ALSO ACT AS BARRIERS TO INVADING WEEDS, AND FUKUOKA'S[3] SYSTEM OF NO-DIG FARMING IS USED.

The edge of the sea, wherever it is, has its peculiar difficulties. Across the great unmodifiable plain of water, winds arrive at gale force, carrying salt and abrasive sand grains. The similarities to both desert and "altiplano" or high plateau country are obvious. Birds, plants, and other species demonstrate that to us by their common occurrence in desert, coastal or montane regions. Waders, choughs, currajongs, crows, starlings, certain berry plants and insects for which these birds act as couriers, also show the same distribution, and some frogs share coast and high plateau or coast and desert in common.

The defences of the permaculturist can therefore be gathered from all these environments, and agaves, yuccas, palms and cacti will be as useful inland as on sea coasts, as will all tough, woolly, thick-leaved, waxy, shiny and needle-leaved trees. All serve the same function—resistance to wind, drying out, and salt or sand. "Corky" barks and fibrous-stemmed species also help to resist sand blast, as does self-mulching such as is found in tamarisk and casuarina. Fibrous palm and yucca stems are notoriously tough. Plant-water reservoirs like the baobab and bottle trees, the fleshy ice-plants, memembryantheum and saltbushes are helpful species, as are the New Zealand coprosmas and the hardy coastal pines (*Auricaria, Callitris*). Certain other species also show promise; the best guide is a visit to exposed gardens near the sea.

Where sea coasts benefit most is in the low incidence of snow and frost, the generally more temperate climate, and a greater frequency of night dews and mists than the dry inland. The great problem is salt-burn, when sea winds blow in dry periods, and deposit salt on leaves. As Lillian Callow points out in *Trees for the Sea Coast* (The Tree Society, 258 Mill Point Rd., South Perth, W.A.) it is the salt death of leaves rather than wind-pruning which accounts for the streamlined shape of trees near the sea.



SEA SIDE PLANTING SEQUENCES. FIG. 5:28

The really valuable front-line plants are those tall and graceful windbreaks that will stand against the first onslaught. Examples are:

Coconut Palm	*Coco nucifera*
Cotton Palm	*Washingtonia felifera*
Canary Palm	*Phoenix canariensis*
Date Palm	*Phoenix dactylus*
Norfolk Island Pine	*Auracaria excelsa, A. heterophylla*

5.3	Macrocarpa Pine	*Cedrus macrocarpa*
	Rottnest Island Pine	*Callitris robusta, C. tamarria*
	Oyster Bay Pine	*C. tasmanica*

Behind these, lower bushy species, some very hardy, suppress the ground wind and form thickets or hedges.

Boobyalla and Acacia	*Acacia sophorea, A. cyclops, A. myoporum*
Banksia	*B. marginata, B. serrata, B. attenuata, B. menziesi*
Tamarisk	*Tamarix aphylla, T. parviflora*
Carob	*Ceratonia siliqua*
Cape thorn	*Lycium ferocissimum*
Crested Wattle	*Albizia lophantha*
Coprosma	*Coprosma repens, C. retusa, C. kirkii*
Buddleia	*B. salvifolia, B. globosa*
Metrosideros (N.Z. Xmas tree)	*M. excelsa*

And within the garden, lower hedges of

Rosemary	*Rosemarius officinalis*
Wormwood	*Artemisia*
Euonymus	*E. japonica*
Chilean barberry	*Berberis darwinii*
Pampas grass	

In damp areas, hedgerows of coastal ti-tree (*Melaleuca*) may be pruned or unpruned, and provide useful stakes and poles. Some of these species are: *Melaleuca pubescens, M. hypericifolia, Leptospermum laevigatum, M. flavescens.*

As the first ranks decrease the wind, a complexity of more useful species follow, such as

Olive	*Olea europa*
Carob Bean	*Ceratonia siliqua*
Kaffir Plum	*Harpephyllum caffrum*
Bamboo species	

Quinces, and the usual mix of stone fruits and citrus.

Nectarines, in particular, appreciate the mild winters. And, eventually, a complex of legumes and fruit species in sheltered nooks, only a few hundred yards from the coast. On hillsides and in less exposed areas, most needle-leaved pines (*P. pinea, P. pineaster, P. radiata*) thrive and provide the acid mulch which offsets the alkilinity of desert and coastal gardens, or provides the mulch for blueberry crops.

Both in deserts and on coasts it is advantageous to shelter early plantings with fences or trellis, and to use these as frames for low climbers, many of which are also creeping species useful for ground cover.

Kennedia prostrata is recommended as a good leguminous mulch by Ruth Geneff of Perth, while Mesembryanthemum, Dolichos, Tecoma, and Tetrogonia species, amongst others, prevent sand drift and keep soils from drying out. Many local fleshy or tough creepers can be found on coasts. Lupins too, both annual and perennial varieties, thrive as coastal scrubs, and add to soil fertility, binding loose sand as they do so. On rocky, exposed headlands, *Quercus ilex* (an evergreen oak), *Casuarinae equisetifolia* and *Callitris* spp break the winds for later inland development.

In homestead and self-sufficiency design, even redundant structures and earthworks can be designed to modify climatic extremes, to provide niches for important or preferred plants, and to reduce active energy needs. Thus, aspect of slopes is critical in deciding between drought-resistant and damp-tolerant species. Every building has these "aspects", and by trellis construction, their effects can be increased.

In new gardens, the great lack is wind shelter. Species such as citrus, avocado, and macadamia struggle to survive. Thus, the fastest possible assistance in these cases is to build trellis at near right-angles to E., W. and N. walls. Such trellis has a multiple effect: it separates functional space into recreational, garden, or service area; prevents the flow of cold winds along walls (and acts as a sun trap) and itself presents a basic structure for vine crop.

Trellis built on earth banks, tyre or stone walls, at rockery bases are even more effective as early protection. They may curve out from the house corners, or simply break up a facade on a school or large building, thus affording several places for benches, lawns and gardens.

Frequently, in institutions, large building surfaces converge to make wind tunnels. Trellis is often the only answer, and arrowed entries baffle the wind further. Similarly, roads of no real thoroughfare value are mostly designed as clear wind tunnels. Large boulders, plants and trellis convert them to sheltered and sinuous access, and block dust, cold and noise as a side effect. This is true of all driveways, service roads, blind entries and minor trafficways.

Horizontal trellis has several uses:

- to shade windows from full summer sun;
- and to create overhead vine trellis to shelter tender crop in desert or extreme summer climates; and
- to increase the solar radiation on crop.

The refreshing coolness of a shadehouse in the hot Australian summer has to be experienced to be believed. Even tiny pools, a few ferns, and a spray or drip of water increases the effect, both physically (by evaporation) and psychologically. Air in such places has a different quality, an aliveness normally missing from the languid air of still areas.

Trellis can always be backed up by permanent windbreak, and as this grows, trees can evolve with their shelter growing to protect them. Additive features are the reflection or radiation from walls and ponds; some of these are figured, but even so we rarely see a glasshouse constructed with a reflective pond to the N., or a solar pond as heater.

By just rounding a corner, the climate alters from one suited to the soft herbs such as celery, parsley, chives (and strawberries) to a dry, hot site suited to the aromatic herbs, and producing many more oils.

6 STRUCTURES

Man lives in a built environment, in all climates. His shelters are at the core of the zonation system of permaculture, and whether he builds for himself or his livestock, it is essential that the new buildings are so constructed as to supply their own heat and at least some food. It is in buildings that most domestic energy is consumed, where we survive the extremes of heat and cold, and where we may supervise and plan the evolution of our life-support systems.

It is self-evident that a diverse garden becomes a source of a variety of foods that do not need to be cooked, so reducing the need for cooking fuels. The old emphasis on grains and pulses has created a demand for fuel that countries, like India, can not afford. Nuts, fruits, greens, and many root crops need no cooking, and are of equal or superior food value. The homely strategies of cooking in one pot food that needs only reheating, and of cooking for a larger community are also important for fuel conservation.

While the greatest waste of energy is in irresponsible industries like those which produce packaging, newspapers etc. and gas-guzzling motor vehicles, the householder should aim to achieve the least energy use for his own sake, and at the same time attack the rationale of energy-wasting at the industrial level.

6·1 THE REACTIVE HOUSE

One can do no better than to read (or reread) Kern[32] for inspiration on passive climate control in housing, but, as he points out, locally developed systems are evolving that suit specific climates, and many architects are (or should be) aware of the cheapness and benefits of structural control of heat and cold (though, as yet, I see no evidence of this in Tasmania).

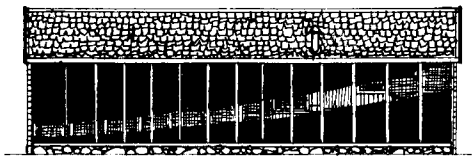
People will spend enormous sums on house materials, land, and plants, often without consulting the (cheap) design books that would save them much greater sums in future maintenance and upkeep. And many houses are already built, or being built, without any thought of future oil shortages and present rising fuel costs. For this reason I have included data on the late adaptations that can be made to established housing, as well as some strategies for future buildings.

The whole thrust of reactive house design is to reduce or eliminate the need for external energy input for climate control. Because the sun heat is regulated and stored in the heat masses of floors, walls and water tanks, and draughts are excluded, then the very slight heat yield from body warmth, cooking, and perhaps a small pot-bellied stove is all that is needed to keep the air space warm.

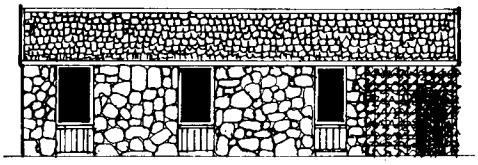
What can be added to the architectural designs are biological aids, as turf roofs, wall and roof creepers for external insulation, glasshouses and shadehouses for food production and climate modification, and thus a better integration of the house and the external environment. But, to start with, all people building or buying houses need to know the basic principles of the reactive house (Fig. 6.1). An essential book for all Australians is that of Deborah White[8] and the Melbourne team who worked on this and other energy problems. For other designs see *Co-Evolution Quarterly,* Summer '78 and subsequent issues.

The essentials of a reactive house are:

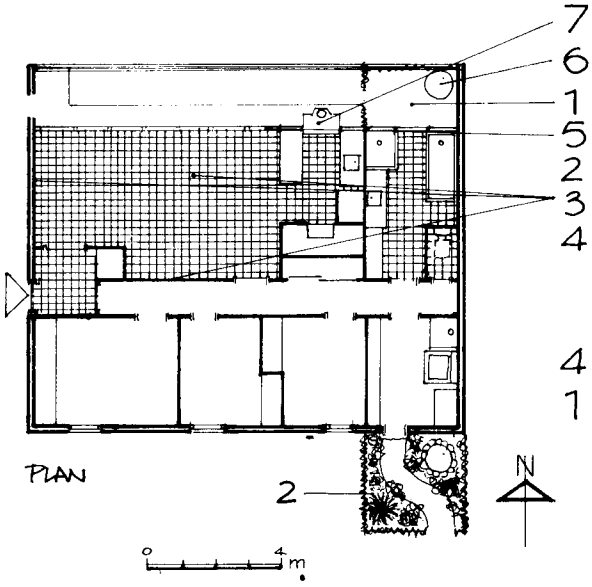
- it is sheltered from cold winds, hence needs designed windbreak planting (see Fig. 2.5);
- it is oriented on an east-west axis, facing the sun. Thus, an attached glasshouse is feasible;
- there are no windows, or very small fixed windows in the E. and W. walls. These walls are then available for external vine crop insulation, trellis, or shrubbery;
- there are few windows and doors in the S. wall, and thus shadehouse attachment is facilitated (see Figs. 6.1 and 6.2);
- the whole house and every opening is very well sealed for draughts. Only essential vents (very small) in toilet and bathroom need to be open at all times;
- in areas with hot summers the N. aspect is shaded by deciduous trees or vine crop. These are omitted in cooler areas;



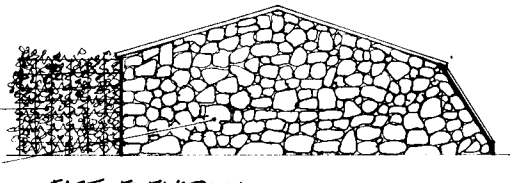
NORTH ELEVATION



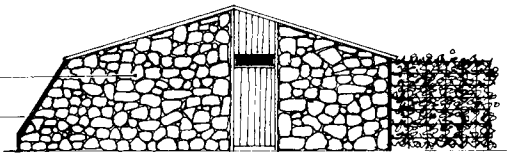
SOUTH ELEVATION



PLAN



EAST ELEVATION



WEST ELEVATION

1 GLASS HOUSE ALONG FRONT WALL: HEATING SYSTEM, SEEDLING PROPAGATION, GROWING OF VEGETABLES (UNSEASONAL) AND PERENNIALS NOT NORMALLY GROWABLE.

2 SHADEHOUSE IN MOST OF TEMPERATE, SUB TROPICAL, + TROPICAL AUSTRALIA: COOLING SYSTEM - POND WITH DRIP, FERNS, SHADE PLANTS. VENT AS IN FIG. 6.2

3 HIGH THERMAL MASS FLOOR AND WALLS (CONCRETE, STONE, QUARRY TILE, EARTH etc).

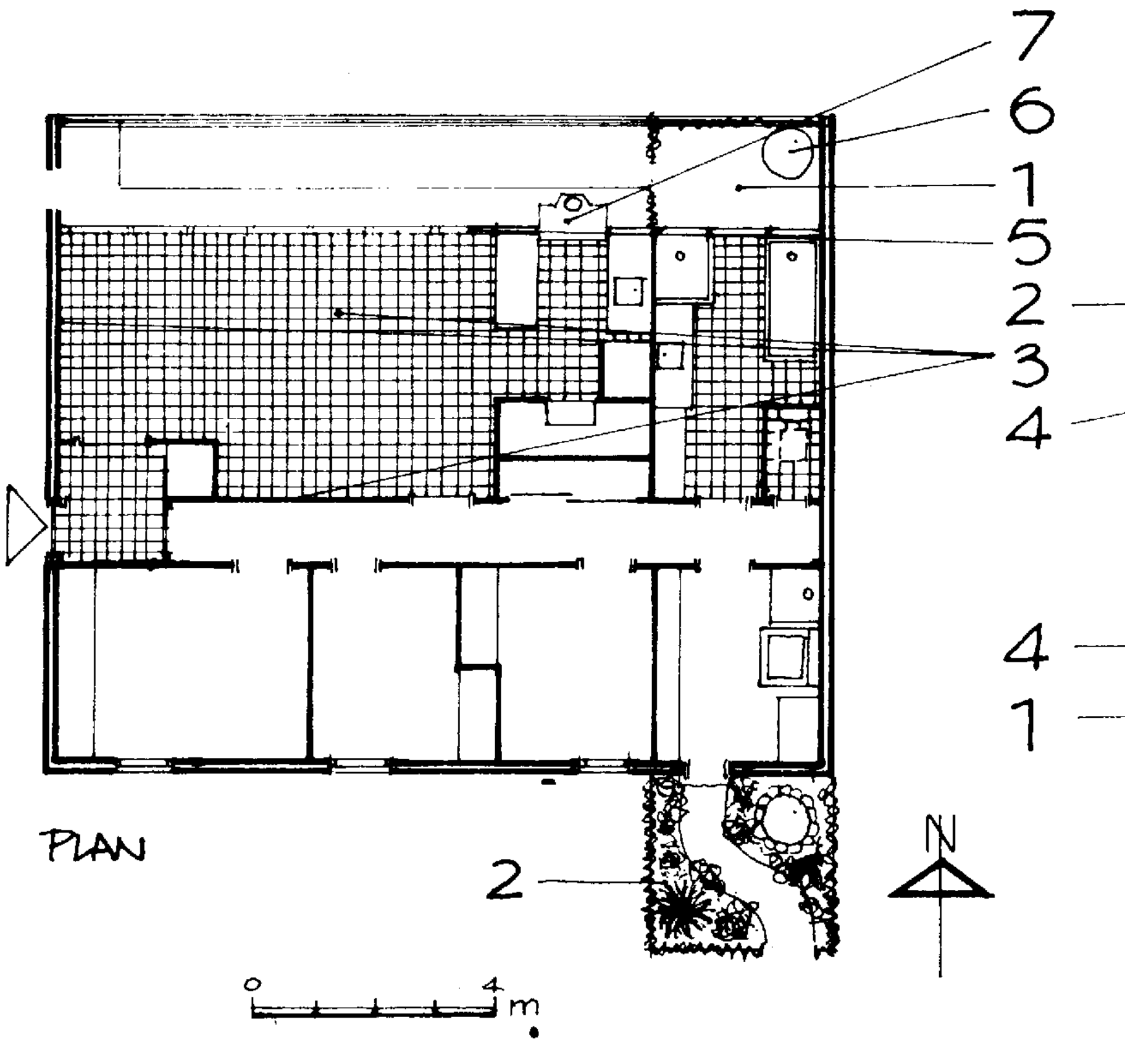
4 NO WINDOWS IN EAST AND WEST WALLS, FEW IN SOUTH WALL.

5 GLASS WALL WHICH CAN BE OPENED INTO GLASSHOUSE (SLIDING GLASS DOORS) PLUS FLOOR TO CEILING HEAVY, LINED, AND PELMETTED CURTAINS.

6 GREY-WATER HOLDING POND (FROM KITCHEN AND BATHROOM) RELEASING WASTE HEAT INTO GLASSHOUSE. OVERFLOW VALVE RELEASE TO ANNUAL GARDEN IRRIGATION, OR DUCK/FISH POND.

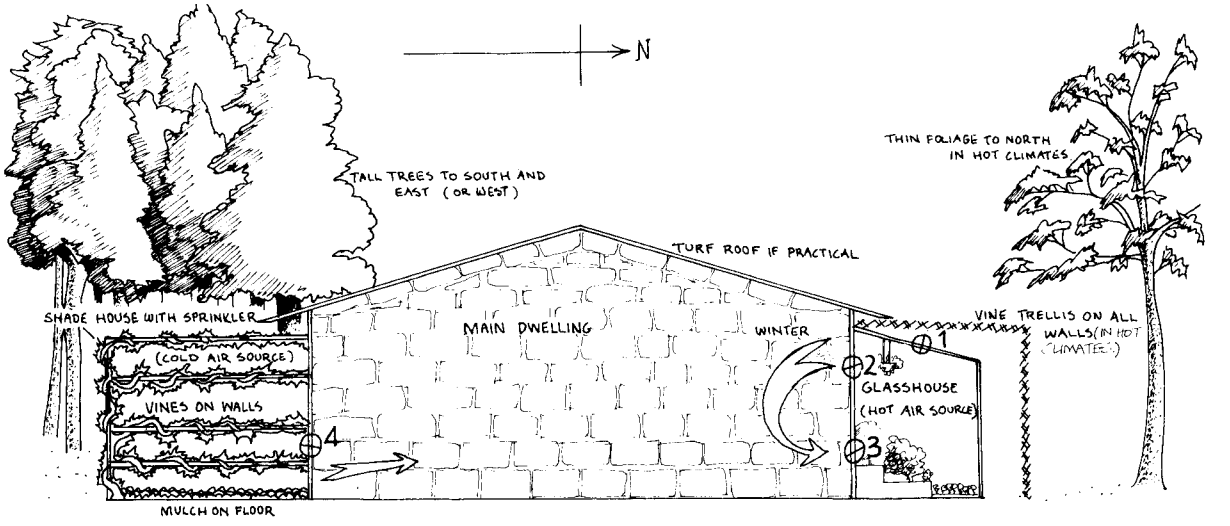
7 POSSIBLE SLOW COMBUSTION STOVE RADIATING FLUE HEAT INTO GLASSHOUSE.

LOW ENERGY, COST EFFECTIVE DWELLING. FIG. 6.1
(MODIFIED AFTER COLDICUTT AND WHITE[8]).


7
6
1
5
2
3
4
4
1
2
N
0
4
m
PLAN

- all walls and ceilings, and the perimeter (1½ m) under floor slabs are insulated. Seagrass (*Zostera*) is the safest insulation, but insulation made from treated waste newspaper is also efficient;
- massive structures such as chimneys, floor slabs, brick walls, tanks of water etc. are (where possible) *inside* the insulation barrier and therefore act as heat banks. The ideal house is "reverse brick veneer": bricks used are inside the house insulation[8];
- the eaves of the house, and the height or depth of windows are so adjusted that winter sun strikes the full width of the front floor slabs, and that the summer sun does not reach the walls (Fig. 6.21);
- all windows to the N. and S. are fitted with heavy, floor to ceiling, well-fitted, pelmetted, curtains or blinds.

Such homes are not only cheaper to build and cheaper to maintain than houses which need oil heaters and fireplaces, but most importantly they enable people to survive in warmth and comfort without recourse to oil-based fuels. It is no longer necessary, nor perhaps even sensible, to build any other type of house than one which saves or generates energy.



⊕ 1~4 ARE VENTS OPEN 2 AND 3 IN WINTER.
OPEN 1, 3 AND 4 IN SUMMER.
EVERGREEN VINES TO SOUTH (TECOMA, PASSIONFRUIT, etc.)
DECIDUOUS VINES TO NORTH (GRAPE, etc.)

FIG. 6.2: HOUSE MODIFIED BY ATTACHED SHADE HOUSE AND GREENHOUSE, TRELLIS, VINES. SEE ALSO REFS. 8 AND 34.

2 HOUSE MODIFICATIONS

Changes to existing structures follow the same set of criteria. An attached glasshouse to the north and a shadehouse to the south (Fig. 6.2) plus sun-trap planting, trellis, and insulation go a long way to reforming an existing house. The main problem areas lie in the often perverse arrangement of rooms in older houses, many of which face the road rather than the sun, and in the mania for glass windows in all outside walls. (At least the glass is available for more sensible use, or for double-glazing smaller window areas.) We can summarize ways to make older houses more energy-efficient, as below:

- the planting of sun trap trees, attachment of trellis or shrubberies to the S.E. and W.;
- attaching a glasshouse to the N. side if possible;
- attaching a shadehouse to the S. side in hot summer climates (Figs. 6.1 & 6.4);

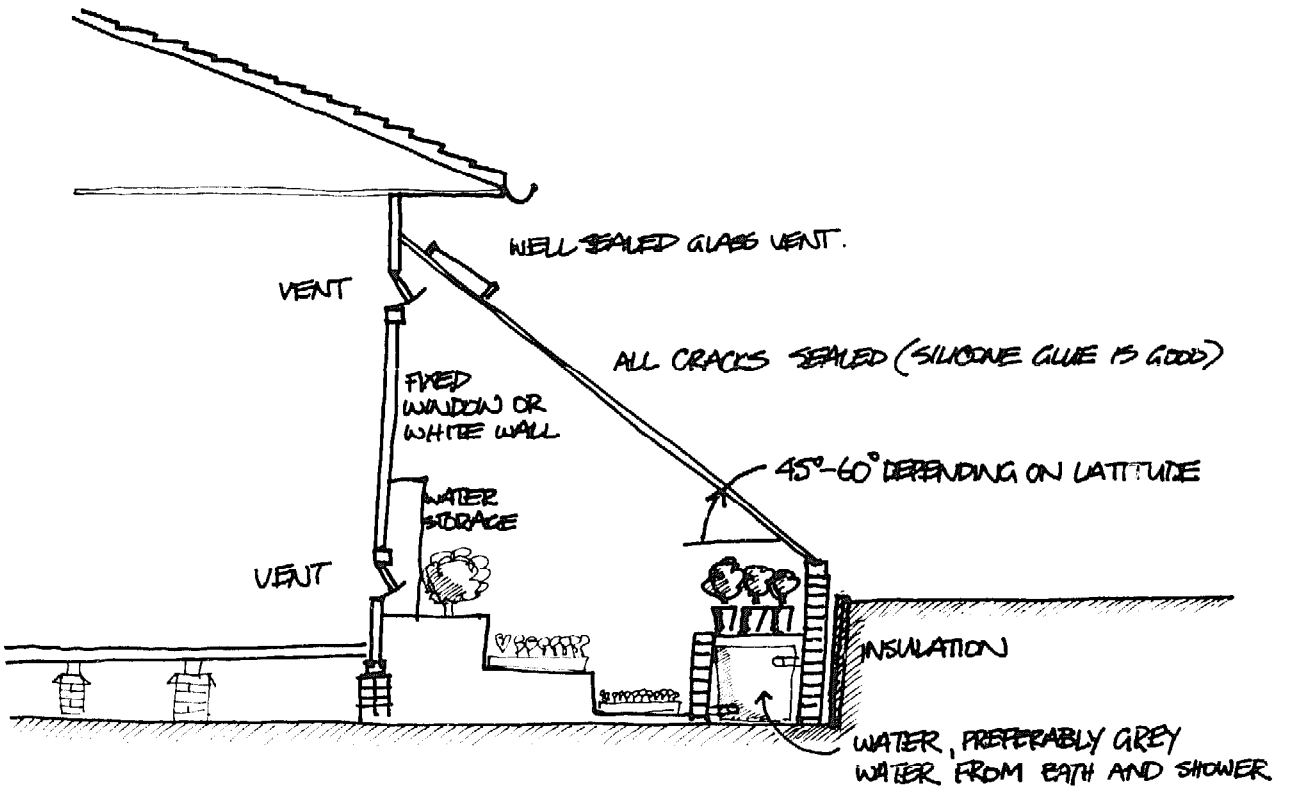
- careful draught-proofing and reduced ventilation (block all old ventilators);
- insulation of ceilings. Vines or trellis along E. and W. walls; and
- adding heat mass as concrete slabs, tanks and brick or stonework within the glasshouse or insulated warm rooms.

The basic references for attached glasshouse design are Fisher and Yanda[14] and McCullagh[15]. An attached glasshouse has the following essential features:

- it may be oriented to within 60° of due N. (towards open mid sky rather than N.);
- E. and W. walls should be insulated, and of solid construction;
- base should be insulated, especially around foundations;
- wooden frames to be used to prevent heat escape (metal frames lose heat too quickly);
- single glass panels are the most durable and efficient glazing;
- if a pit is dug below grade as the base, less heat is lost to the outside ground;
- a very well-sealed top vent is essential;
- water in small containers is the best heat store; pools help, and these may be placed below benches;
- the glass to be at about 45° to the ground for greatest efficiency; and
- plain white paint to S. walls reflects heat efficiently.

If it is necessary to vent heat in winter, then more heat storage needs to be added to capture the excess heat, so water-filled containers are perhaps the most simple way to do this.

Fig. 6.2 diagrams how the system works. In *summer* when the house is too hot, open V.1 at the top of the glasshouse: air escapes, drawing in cool air from V.4, over the damp mulch and through the vine-covered and ferny shadehouse, where a fine spray or drip of water on the mulch keeps the air cool. *In winter* close V.4 and V.1, open V.2 and V.3, so that by day warm air from the glasshouse circulates in the insulated rooms. Close at evening, trapping warm air. Both shadehouse (for small fruit and brassicas) and glasshouses (for spices and tropicals) yield food for the family while cutting down on fuel costs. So, we eat more cheaply and better, and live more comfortably by installing these passive energy systems.



ESSENTIALS OF THE ATTACHED GLASSHOUSE. FIG.6.3

Fisher and Yanda[14] deal with at least part of this system—the glasshouse, but all those who have a shadehouse can testify to its beneficial effect in the Australian summer. In public buildings, as in a school designed with Sweetnam and Godfrey (Vic.) by the author, a *central* shade area allows cool air to be drawn into all courtyard buildings, and gives a refuge for teachers and children in extreme summer heat. Even the dripping of water helps, as does the sight of ferns in a droughted landscape.

Water tanks, often regarded as so outre and old-fashioned that a street in Perth (W.A.) took up a petition to have the tank of a new (ex-farmer) resident removed as "unsightly", can be vine covered in the shadehouse as a cool air/water block. (The snooty residents didn't win—the farmer still has his tank, and they have water restrictions and salted soil.)

In really cool climates, trellis at right-angles to the walls decreases cool wind and forms warm air pockets to the N., and by arranging hot-water usage to the N. side of the house, a double benefit is arrived at:

1 solar ponds can be filled either outside or inside the glasshouse for hot water provision; and
2 heated water from sinks, showers, and baths can be released into a cooling-off tank inside the glasshouse (see Fig. 6.14).

6.3 THE BASIC SUN/WIND DEFENCES OR ALLIANCES

Structures breasting the wind should be like a vessel breasting the sea, either "easy" in entry like a sharp-bowed boat, or permeable, like a raft, or both. Thus Figs. 4.5 and 4.6 suggest a 'U'-shaped suntrap, curved and permeable back to the cold winds, and facing N. The figure shows "even" wings on the 'U' forms, and a due N orientation. This may not be the best shape or orientation for every site, for instance, if a local site features salty and strong easterlies (such as howl about my house and garden as I write) then the 'U' should be higher and longer to the E. than to the W. If mornings are sunny and clear, and evenings cloudy, or the sun sets early behind

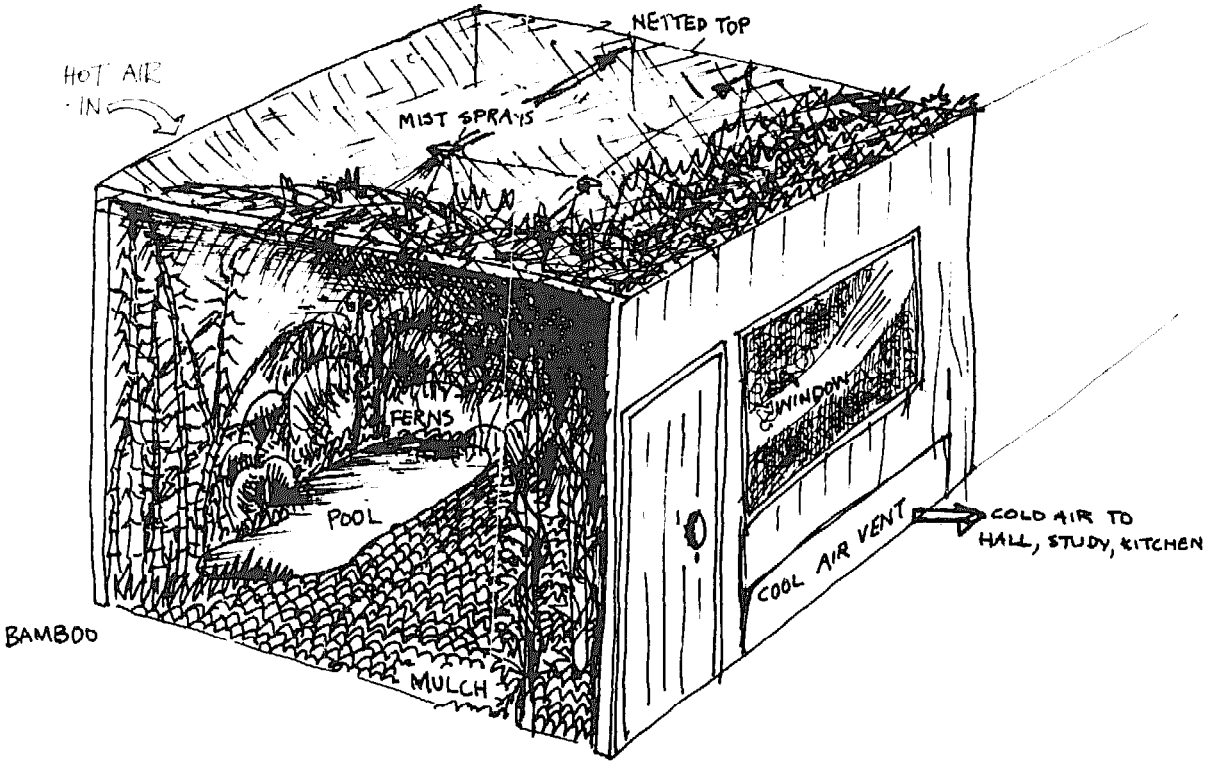


FIG. 6.4: SHADEHOUSE — OFF KITCHEN, STUDY, LAUNDRY, HALLWAY WINDOW, TO SOUTH.

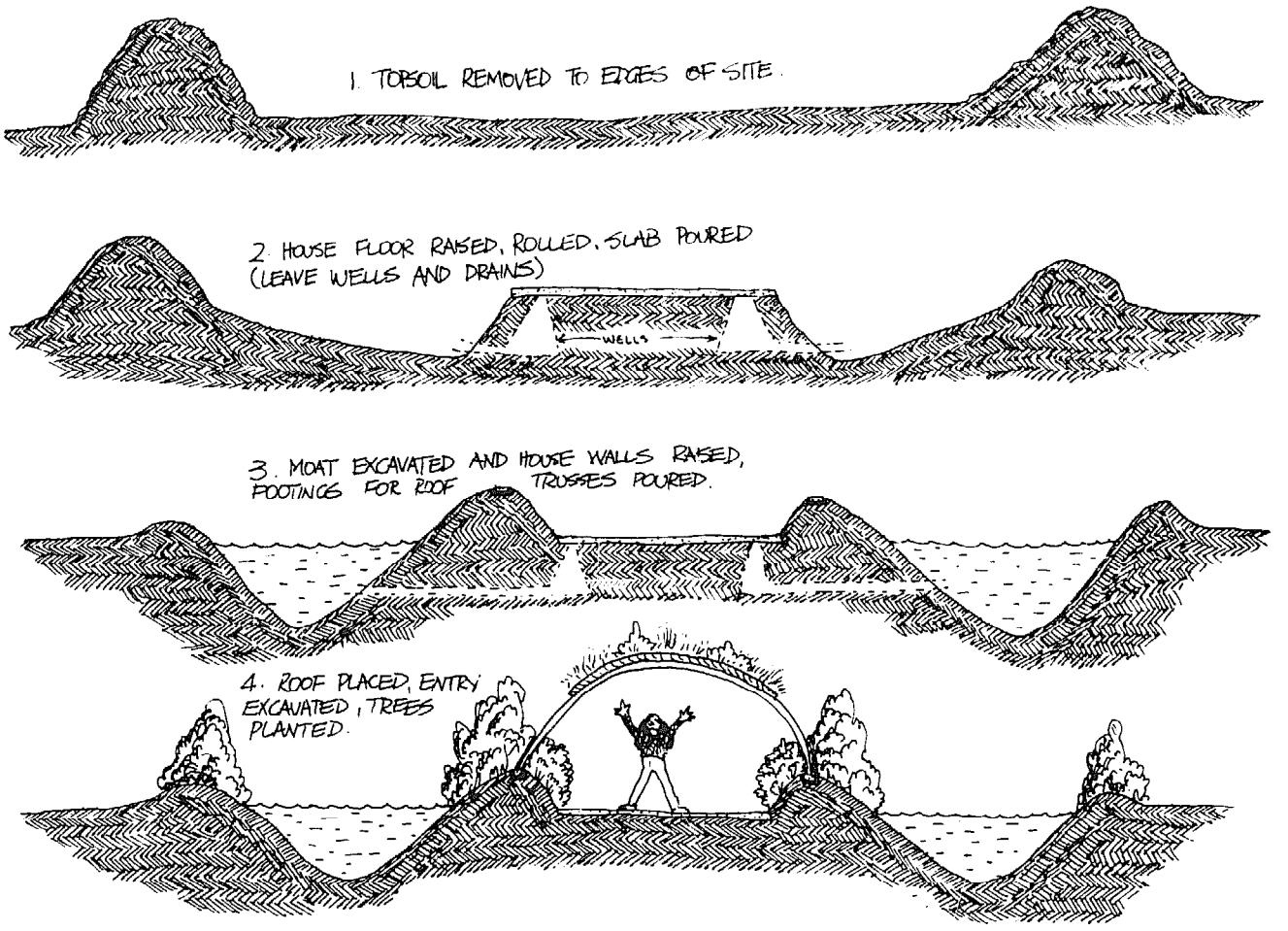
a western hill, the 'U' should be swung towards the NE. to gain most sun. On very hostile, dry, windy, shoreline, or cold sites, a whole series of interlinked sun traps may the only sensible way to plant.

Note that in wind-protection 'nets' (see Fig. 4.6) the corner junctions (as on the left) give 'squarer' fields than do centre junctions, as on the right. Similarly, sun screens may be curved and tapered to admit low and early light, based on the known path of the sun.

SOME NOVEL HOUSES 6·4

Earth Houses 1

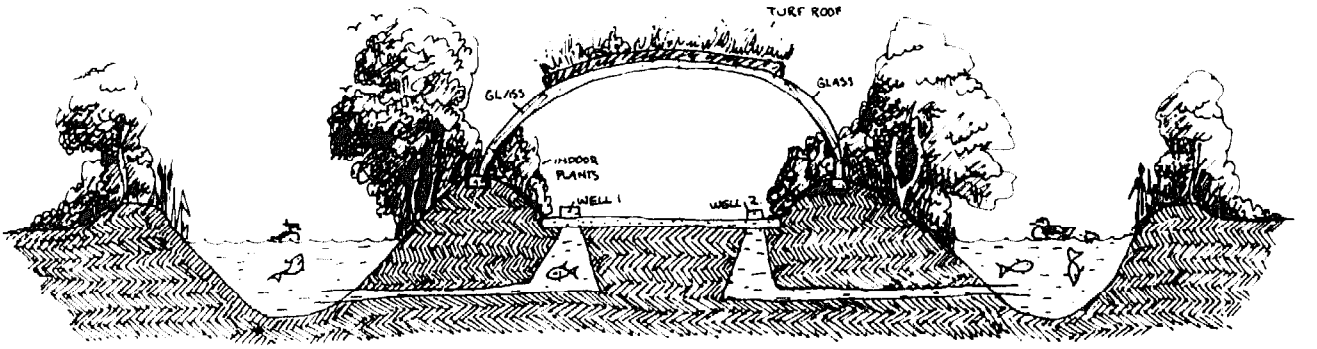
While working in the icy and windswept plains of highland Tasmania in the 1960's I had the job of stripping trout eggs in midwinter snow, and of transferring fish to less densely stocked and therefore more productive waters. By chance, roadmenders raised an earth bank about 1.8 m high behind our frigid cabin, and thereby made a dramatic change in climate. By insulating us from the winds to the S. and by trapping sun heat to the N. our hut was made much more comfortable. Larger bushes eventually grew on the spoil heap than on the plain, and this led me to evolve the idea of an earth-house for bleak, cold, windswept and hostile areas. The design for this follows, and in the opinion of Ken Yeomans and other expert earth-workers, the house is both practical and cheap to make, even as a shelter for animals or a storage shed.


1. TOPSOIL REMOVED TO EDGES OF SITE.
2. HOUSE FLOOR RAISED, ROLLED, SLAB POURED (LEAVE WELLS AND DRAINS)
WELLS
3. MOAT EXCAVATED AND HOUSE WALLS RAISED, FOOTINGS FOR ROOF TRUSSES POURED.
4. ROOF PLACED, ENTRY EXCAVATED, TREES PLANTED.

CONSTRUCTION STAGES OF EARTH HOUSE. FIG. 6·5

6.4 The developed earth-house has all the insulation factors of vegetation and earth, plus a moated water supply, indoor wells for waste disposal and water supply, frost-clear roof as an indoor glasshouse, and the whole structure would cost less than $1,000.00 to construct, plus floor slab and roof trusses (Figs. 6.5-6.7).

The Pioneer Australian dairy (Fig. 6.8) is, as everyone who has inherited one can attest, a very cool, below-ground storage and fire refuge. Desert dwellings need be of similar "underground" construction.



FIG·6·6 SECTION OF EARTH HOUSE — LIGHT INDOOR DIVISIONS CAN BE MADE. END WALLS OF GLASS TO NORTH, SOLID TO SOUTH.

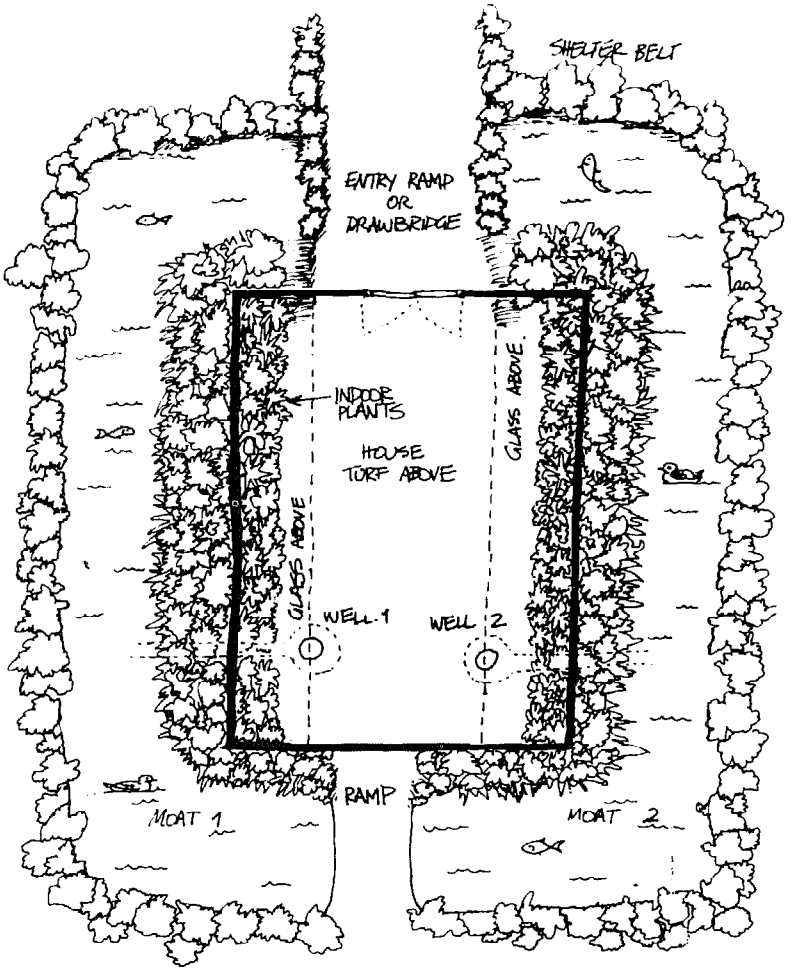
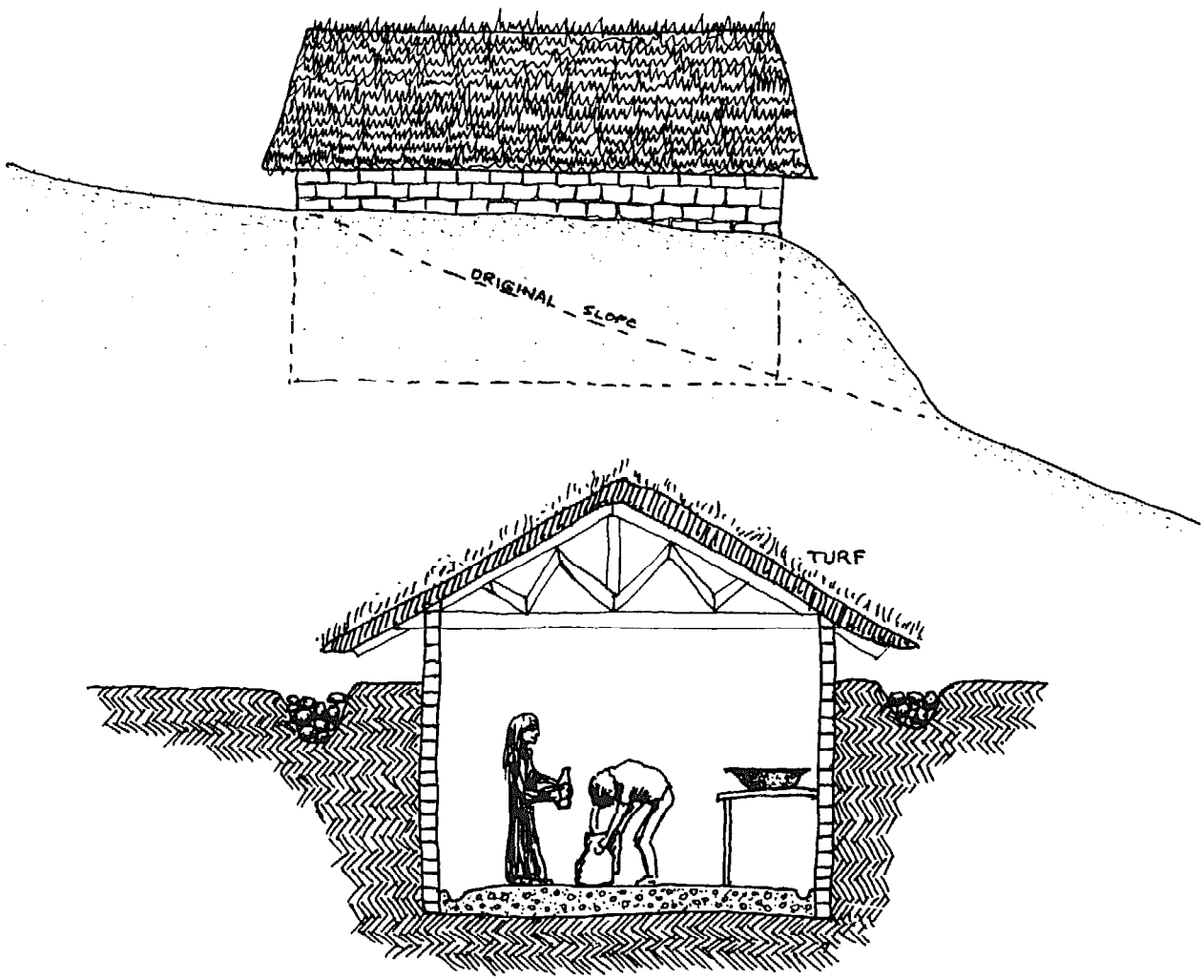


FIG. 6·7: PLAN OF EARTH HOUSE DESIGNED FOR TUNDRA OR WINDY FLAT PLAINS.

There are varying degrees of integration of house and plant—from the totally grown house to vine-covered or sod-roofed conventional structures.

The Sun-Herald of June 18th, 1978, reproduces a photograph of a "biostructure" designed in Stuttgart, Germany, by Rudolf Doernach, which has a fairly conventional light steel and timber frame. This frame is grown over with evergreen, waxy-leaved climbing plants (several species of ivy, geranium, and coastal climbers suit this description), and the result is said to be warm, cosy and weatherproof even in the cold European winter. The occupants are said to benefit from the generally healthier surroundings. Only doors and windows need to be kept clear of vine, and if the structure is designed to take creepers, trimming is unnecessary. The building figured is igloo-like in form.

The same article figures a building which is basically a coralline deposit, using an electrolyte such as the sea or fresh water to deposit chemicals in a free-form metal mesh of any shape—the result is rather coralline-cave in appearance. (Ref: Prof. Wolf Hilbertz, Director, American Inst. for Exp. Architecture, Faculty of Arch., Texas Uni., U.S.A.)



EARTH HOUSE TRADITIONAL BUSH DAIRY CUT INTO BANK, WALLS OF MASONRY, TURF ROOF, TAMPED EARTH OR CONCRETE FLOOR. EAVES PROJECT TO RUBBLE DRAIN. COOL IN ANY WEATHER. FIG. 6.8

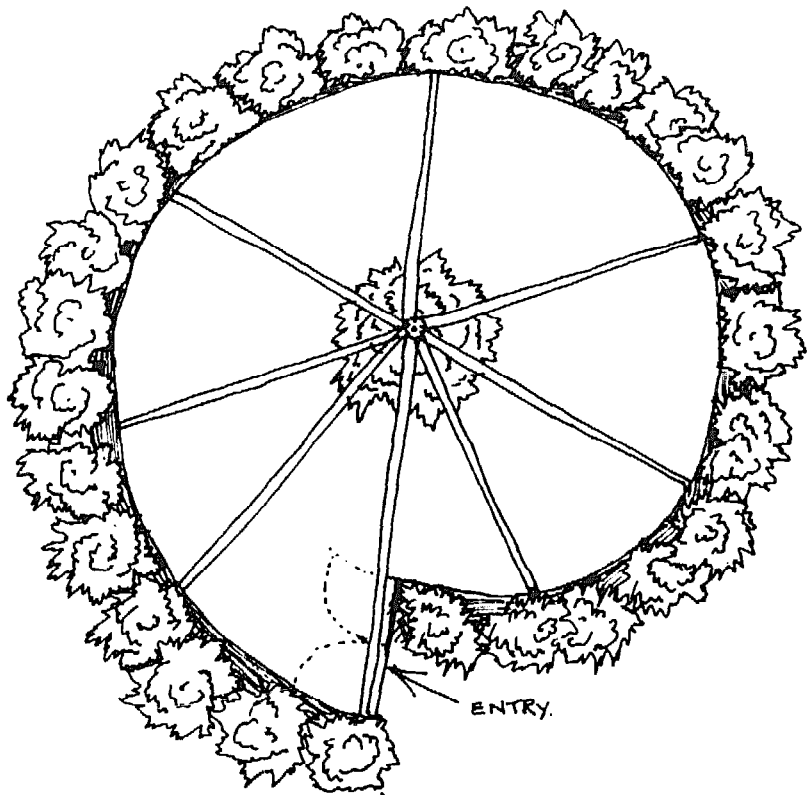


FIG. 6·9: PLANT HOUSE 1 (PLAN). SLAB ON GROUND, SPIRAL OF BAMBOO, POPLAR, CENTRED ON EXISTING TREE, POLE, OR LARGE POPLAR STAKE. WALLS WOVEN AND IVY-COVERED TO ROOF. CHEAP LIVESTOCK SHELTER.

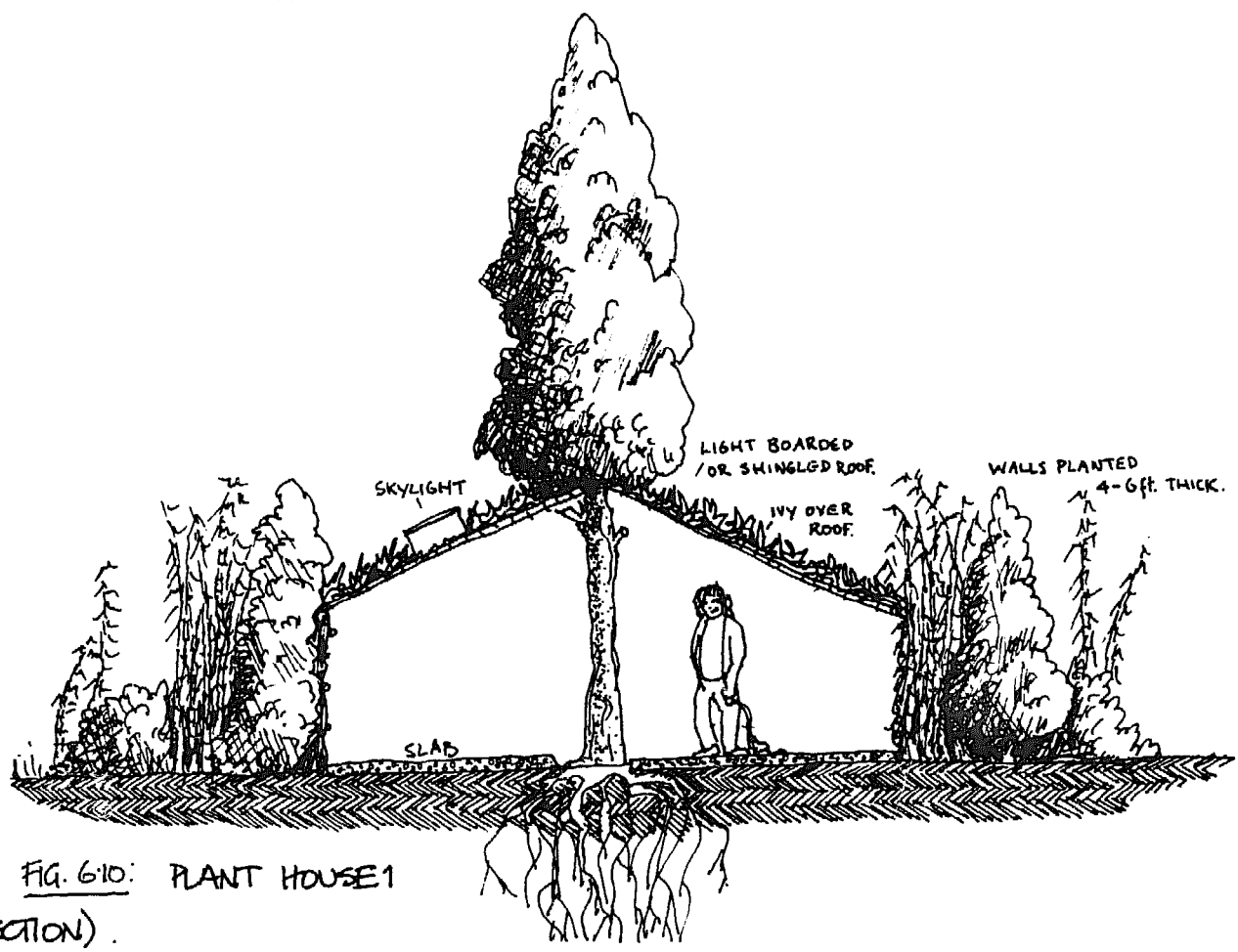
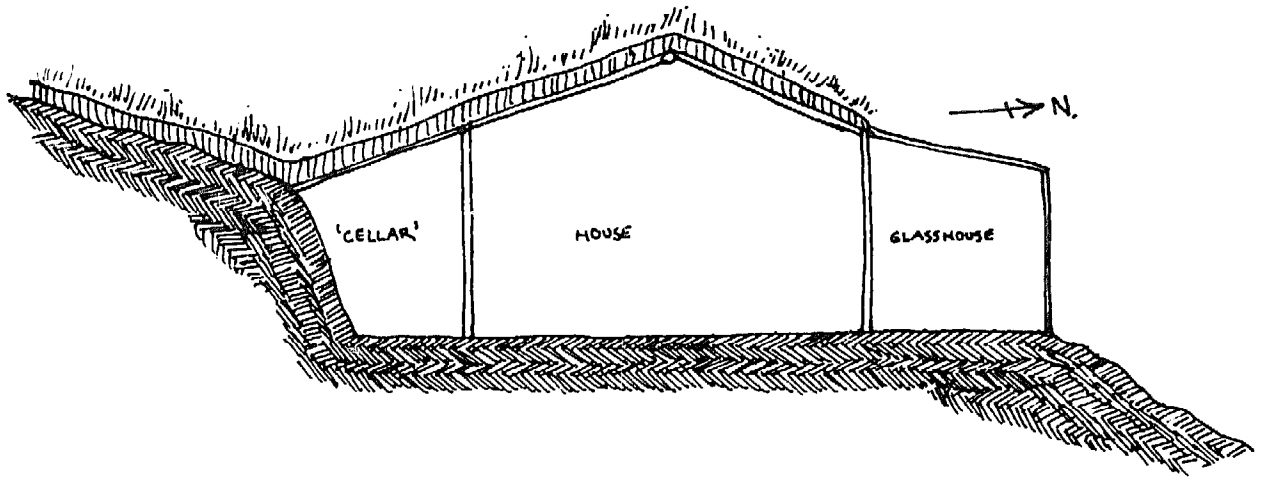
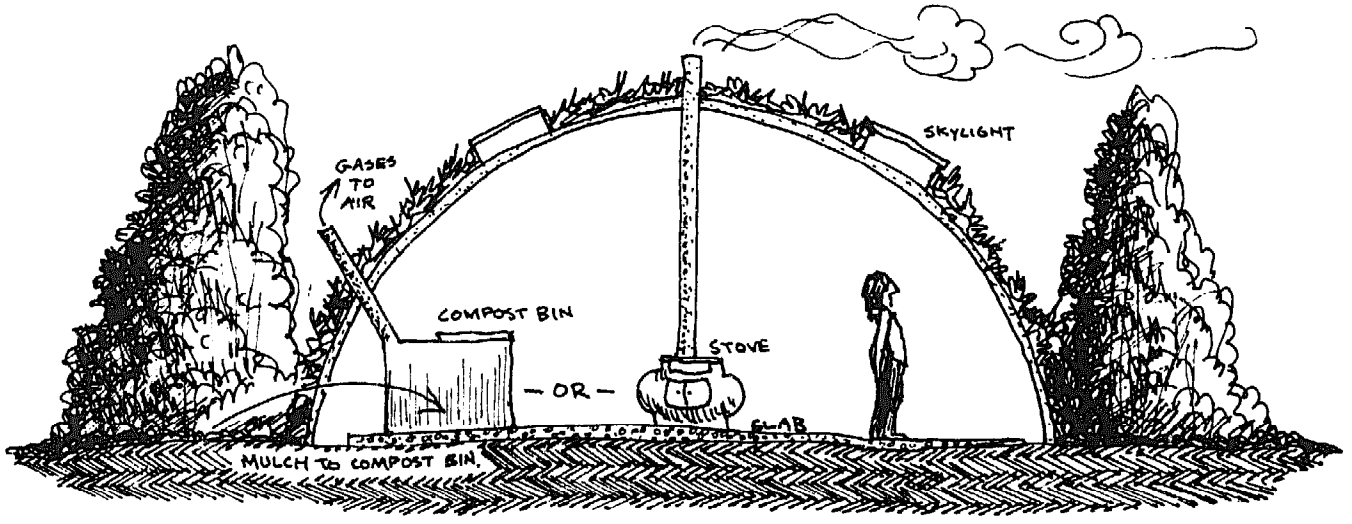


FIG. 6·10: PLANT HOUSE 1 (SECTION).

Here, plants are used as integral parts of the house structure. Fig. 6.9 was designed for a field shelter for domestic animals, but would also be a feasible tropical home. Only very light structural members are necessary. Fig. 6.12 (after Dornach) has the further refinement that a fully enclosed and vented compost box provides background heat. Materials dry-stored in autumn, and "charged" at 3 week intervals in a box of this type would "burn" at about 66°-82°C until composted, rather like a slow fire. Again, placement in a glasshouse or animal shelter is of use.



PLANT HOUSE 2 (SECTION). CONTINUOUS TURF ROOF WITH GLASSHOUSE FRONT, FERNHOUSE AND CELLAR AT REAR. FIG. 6·11



PLANT HOUSE 3 (SECTION). METAL, CONCRETE, PLASTIC OR WOODEN DOME WITH IVY OR TURF COVER, PLANT WALL SHELTERS. (AFTER DOERNACH.) FIG. 6·12

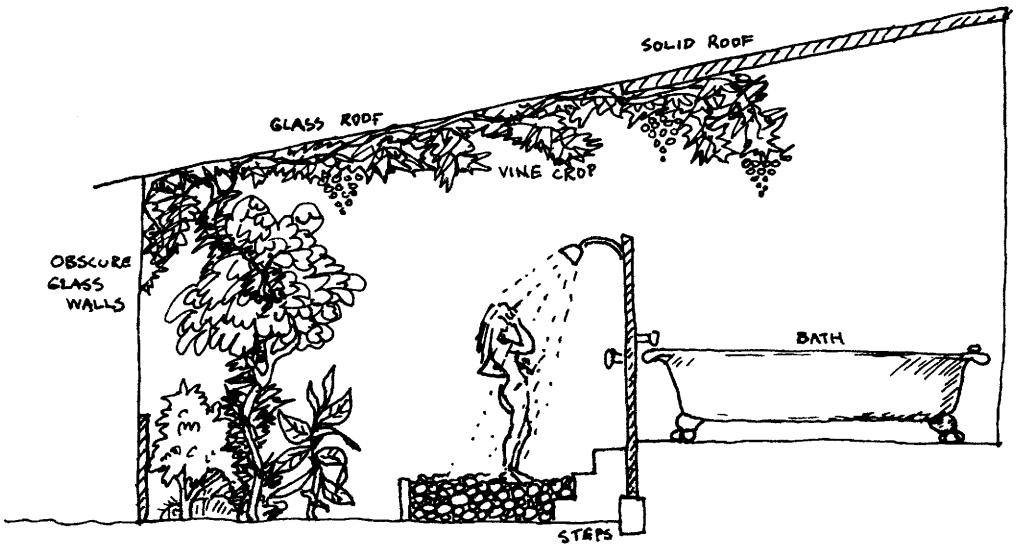
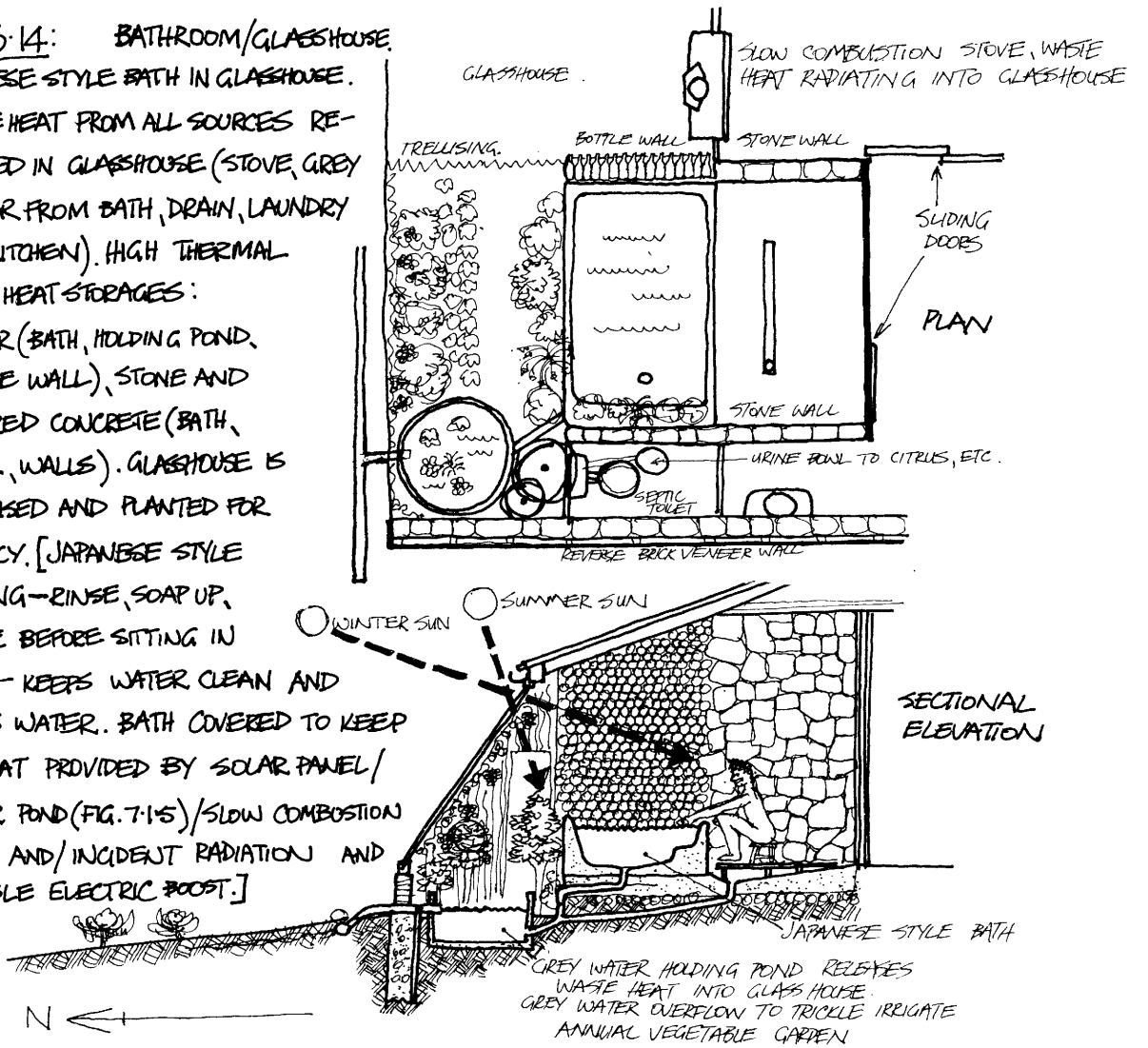
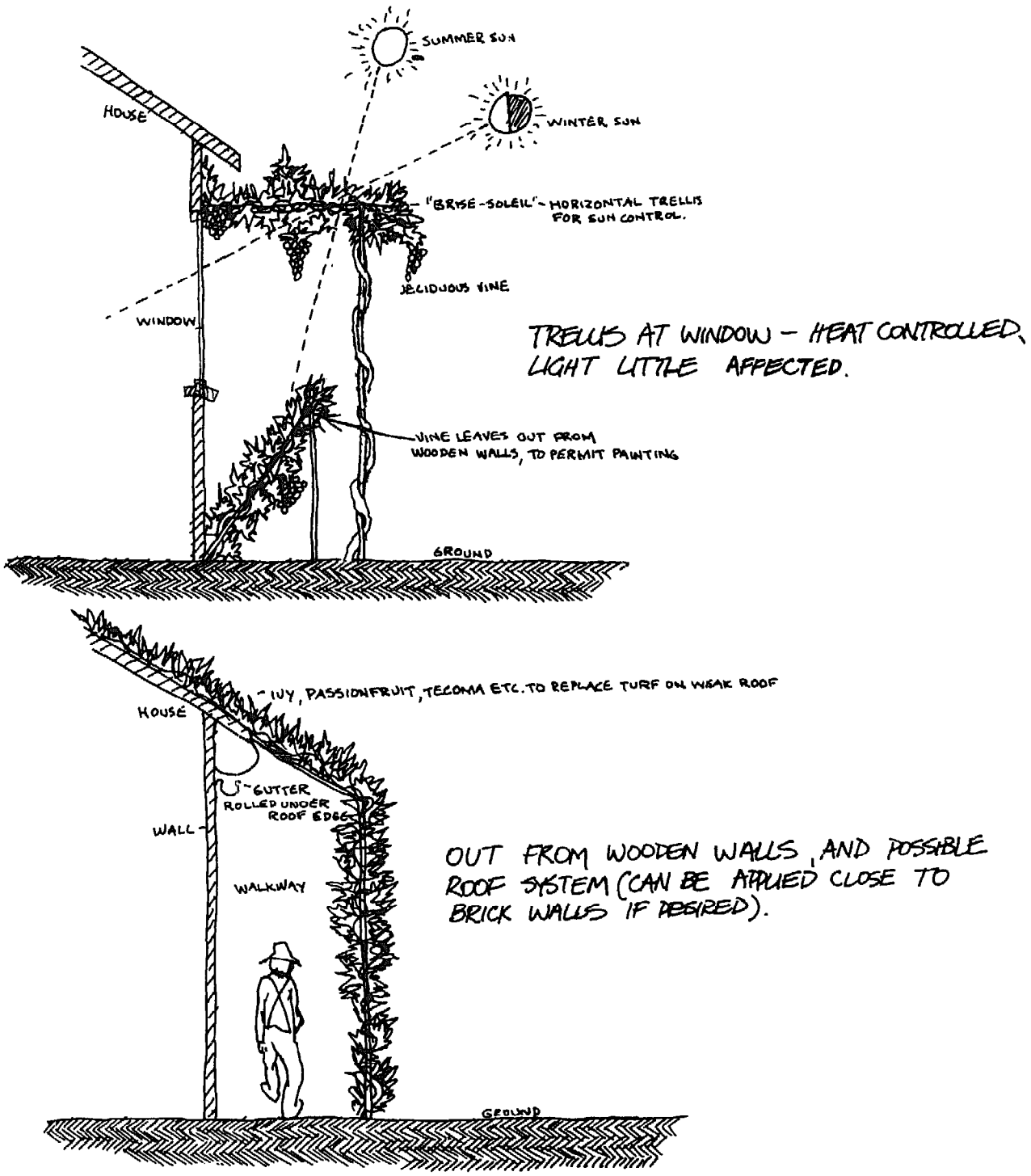


FIG. 6·13: BATHROOM GLASSHOUSE. SHOWER OVER PEBBLE BED KEEPS PLANTS MOIST. CAN BE ATTACHED TO EXISTING BATHROOM AS 'HOT' OR 'COLD' GLASSHOUSE.

FIG. 6·14: BATHROOM/GLASSHOUSE. JAPANESE STYLE BATH IN GLASSHOUSE. WASTE HEAT FROM ALL SOURCES RELEASED IN GLASSHOUSE (STOVE, GREY WATER FROM BATH, DRAIN, LAUNDRY AND KITCHEN). HIGH THERMAL MASS HEAT STORAGES: WATER (BATH, HOLDING POND, BOTTLE WALL), STONE AND COVERED CONCRETE (BATH, FLOOR, WALLS). GLASSHOUSE IS TRELLISED AND PLANTED FOR PRIVACY. [JAPANESE STYLE BATHING—RINSE, SOAP UP, RINSE BEFORE SITTING IN BATH—KEEPS WATER CLEAN AND SAVES WATER. BATH COVERED TO KEEP IN HEAT PROVIDED BY SOLAR PANEL/SOLAR POND (FIG. 7·15)/SLOW COMBUSTION STOVE AND/INCIDENT RADIATION AND POSSIBLE ELECTRIC BOOST.]



The loss of warmth and of cool air, in buildings is most affected by the winds which pass along the walls. Still air or water is the best insulation, and in plants this is the air trapped in a tangle of stems and roots, or the shelter given by screens and shrubberies (see Fig. 6.15).


SUMMER SUN
WINTER SUN
HOUSE
"BRISE-SOLEIL" - HORIZONTAL TRELLIS FOR SUN CONTROL.
DECIDUOUS VINE
WINDOW
TRELLIS AT WINDOW - HEAT CONTROLLED, LIGHT LITTLE AFFECTED.
VINE LEAVES OUT FROM WOODEN WALLS, TO PERMIT PAINTING
GROUND
IVY, PASSIONFRUIT, TECOMA ETC. TO REPLACE TURF ON WEAK ROOF
HOUSE
GUTTER ROLLED UNDER ROOF EDGE
WALL
WALKWAY
OUT FROM WOODEN WALLS, AND POSSIBLE ROOF SYSTEM (CAN BE APPLIED CLOSE TO BRICK WALLS IF DESIRED).
GROUND

WALL TRELLIS FOR INSULATION FROM WIND AND HEAT. FIG. 6.15

Climbers, screens, dense shrubberies and windbreaks should all aim to reduce air-flow around buildings, thus increasing the usefulness of insulation. Holgar Wishart (N.S.W.I.T., in conversation) notes that wind passing over and around solar heaters is the main cause of their inefficiency. For this reason they should be encased inside the roof of the building, lying on the roof insulation and protected by a glass skylight about 50 mm above them, rather than exposed to the winds.

Stephen Lesiuk (in conversation, May '78) measured the gain or loss of heat over bare and vine-covered brick walls in spring, to obtain data on the effects of vines on heat loss and gain. His findings are as yet to be published, but briefly, ivy on brick walls suppressed the entry of about 70% of summer heat excess, and prevented the escape of about 30% of heat from the house at night. Dozens of brick-cavity buildings could benefit from this simple biological insulation.

6·5 MINOR DESIGNS AND TECHNIQUES

1 Sound Walls

One of the annoying (and damaging) facts of roadside and industrial living is noise. While it takes a lot of forest to blanket out some noise, the insulation that we use for walls, and thermal efficiency, helps greatly with noise control, as do massive stone or earthbrick walls. I became interested in the problem in relation to hospitals and old peoples' homes where rest is essential, and in one-storey buildings landscape design can certainly help, especially if this factor is noted early in planning, and space is made available to insulate for sound. (It takes 100 m of forest to cut out 6-7 decibels of sound.)

Sound comes in many wavelengths, and the lowest and highest sounds (long and short wave) need different approaches. Insulation, perforated surfaces, double glazing, "draught-proofing" (all the features that prevent cold from entering and leaving) impede high-frequency noise. Low-frequency sound waves behave more like water or waves, and can "flow over" barriers. Both can be reflected by dished or baffled systems, or absorbed in insulating material (causing a very small heat increase).

Earthworks, vegetation, or insulation all help, and the design of the highways, where earth spoil is too often neatly levelled out, so permitting noise to flow uninterrupted. Well-placed embankments of earthed-over tyres plus good house insulation, as per Section 6.1 is the answer to intolerable noise levels.

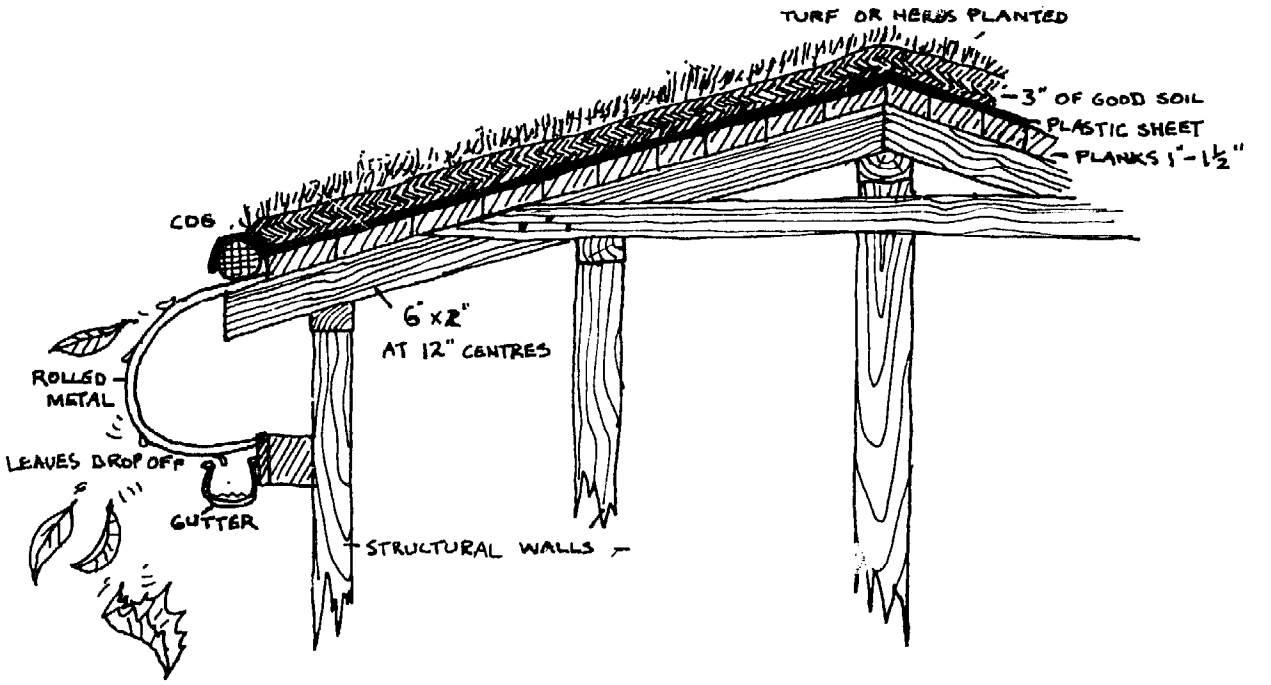
2 The Sod Roof

Sod roofs may be newly constructed, or rolled over strong existing structures, using a plastic film stapled below as a moisture barrier. Chimneys etc. are flashed as usual. The metal roll-under carries water to the spout, while leaves drop off. The slotted angle or log (indispensible on steep roofs) holds the sod from slipping.

Trials of smaller roofs on sheds and animal houses are probably the best way to get the technique (and species) right, and as the weight of winter sod roof is great, loads must be carefully calculated.

I can always bring a nervous titter from an Australian audience by suggesting that they shift their lawn onto their roof. But I am being fairly serious, as sod roofs are great active insulators, and any strong (or strengthened) roof would take sod, either as ready-rolled lawn in humid areas, succulents in dry areas, and with daisies, bulbs, herbs and furbelows to taste elsewhere. The sod root mass effectively insulates; the roof never needs painting, and can be repaired easily if damaged by adding a little soil and seed. If Norwegian models are anything to go by, it should last for 200 or more years, probably longer than the house itself (Williams[9]). For weak existing roofs, especially those of zinc or aluminium cladding sheet, ivy over the roof serves as well, providing the guttering is adapted as shown (Fig. 6.16).

Evapo-transpiration, plus judicious watering keeps the summer heat out, and air and foliage, the winter cold at bay. Sod roofs act, in fact, like ivy on walls. Neither increase fire risk to the house. 6.5



TURF ROOF CONSTRUCTION. FIG 6·16

Fire Mandalas 3

(Figs. 6.17-6.19)

Fire may be trying to get in (to a house or town) or out (from a public fireplace). The orientation doesn't much matter, what matters is that the structures and vegetation are integrated and designed to block fire. A fireproof array of plants is diagrammed below. All are 'sappy' perennials that will not burn, unless permeated by grasses. All are green in midsummer. Sunflower are also included (an annual). Most annual gardens resist fire, as does damp mulch.

If such systems are fenced, and poultry stocked after midsummer, their scratching and browsing greatly decrease the fire risk represented by grasses; or if the system is closely planted and attended to, the chance of fire damaging any plants or structures behind such a barrier are slight.

Windows 4

Colin James (in conversation, Oct. '78) has pointed out to me that the best skylight is, in fact, a clear fibre-glass pool or shallow aquarium, as the water insulates, and gathers light from the horizon. Such pools may need to have 4% formalin added to keep them clear, or else they need to be cleaned regularly to remove fish faeces and plant residue.

No such nuisance deposits occur in wall aquariums, however, and these 'windows' can be stocked with plants and fish, and shaded to prevent algal growth. The fibre-glass tanks of the New Alchemists would serve as windows in normal rooms. As well as preventing heat loss they produce food, recycle nutrients and are of great interest to the inhabitants. What better view than the inside of an aquarium?

Kern illustrates how windows may be better used as vents and air scoops, and also notes that vents may be built without opening windows at all, so that long horizontal, roof, floor, and wall vents can be of solid construction and functional design, while glass in windows remains fixed and therefore more easily draught-proofed.

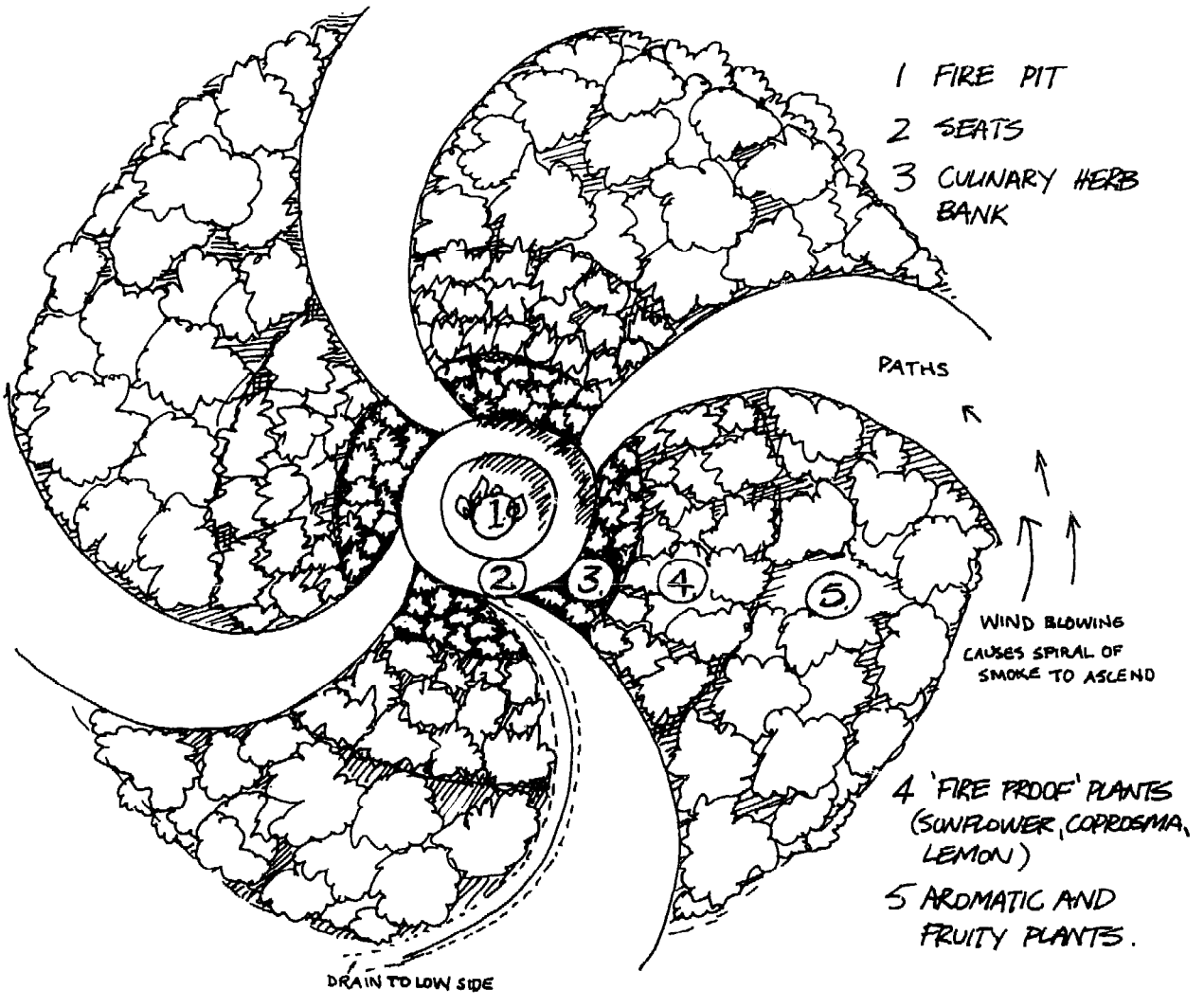


FIG. 6.17: FIRE MANDALA (PLAN).

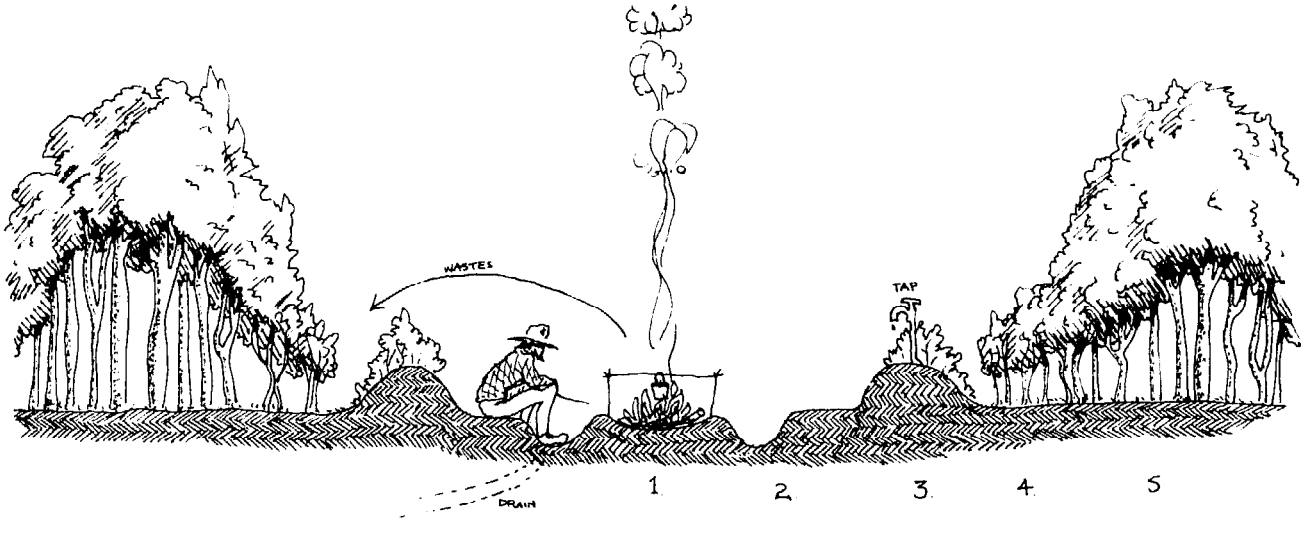
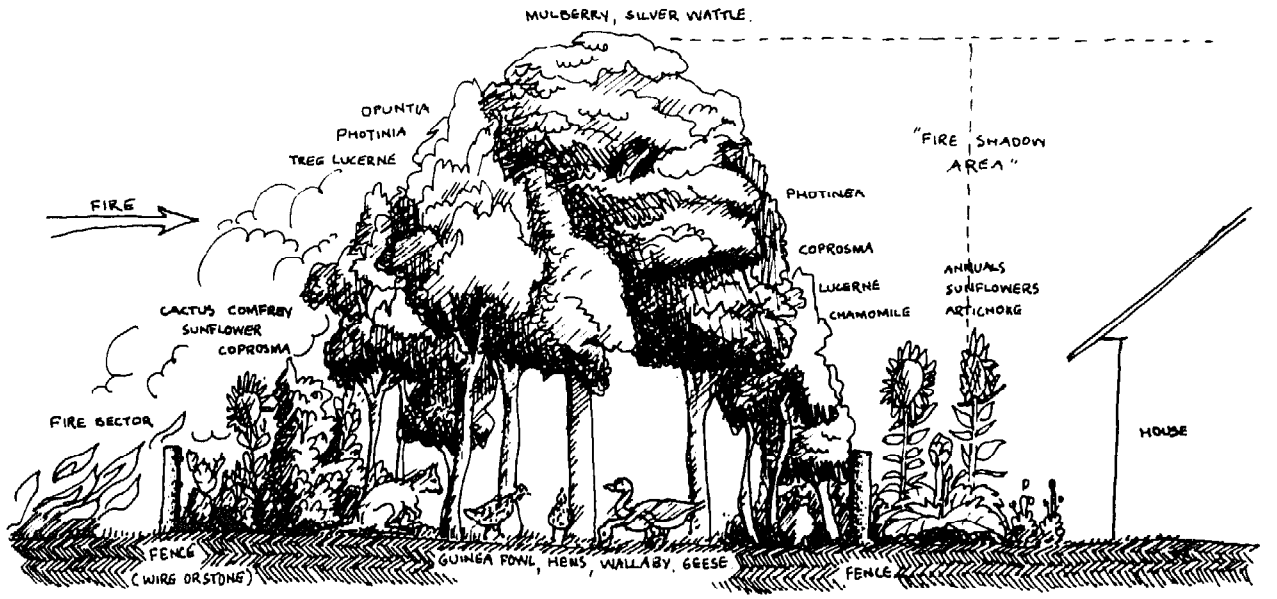


FIG. 6.18: FIRE MANDALA (SECTION).



FIRE DEFENSE PLANTING (WITH LIVESTOCK) — FOR SMALL TOWNS OR HOUSE SITES. FIG. 6·19

Back to the Cave 5

The steady state and cool conditions of caves, brick tanks, walls, fire refuges and root cellars offer great advantage in the storage, preservation and care of a great variety of goods.

Allis Chalmers (W. T. 1978) uses caves to store spare tractor parts because of lack of dust and a dry atmosphere. Cool caves greatly prolong the life of citrus, root crop and leaf crop in store, and are cool air sources in summer. Old mines, wells, and constructed caves below floors have all of these uses.

Also, a cave near the house has value as a family refuge in catatastrophic wind, fire, war or heat wave. Such structures may be dug into banks; underfloor cellars entered from floor traps or outside cellar doors, or above-ground structures of ribbed steel or pipes earthed over for protection. Radiation from fire is prevented by 'T' shapes or a "Dogleg" in the entry of shelters.

Caves under floor are a part of climate control systems, maintaining a constant low temperature (as in Kern[12]) or forming a reservoir to drain cold air off windows at night. Caves or earth shelters outside the house form the essential fire refuge for those who live in areas of high wildfire danger.

Sewage and Other Filthy Matters 6

"Scruple not to enrich the dried up soil with dung, and scatter filthy ashes on fields that are exhausted."

Virgil[10]

It is in the production of dung and ashes that soil nutrients are lost, consequently they are sacred to agriculture in the philosophy of the Chinese. There is a sensible balance between so much nicety that nothing gets done, and common hygiene. Ironically, most health inspectors I know are awfully concerned with germs, but not at all with sprays and industrial residues. Such is life.

6.5 There is no sane technological solution to sewage waste; it is the province of the biologist. Canberra is learning that lesson at great cost: in trying to sterilize sewage by using complex technology they end up with an expensive and dangerous product—chemicalized water. Maryborough (Vic.) has taken steps towards sanity in sanitation, using water and soil to deal with the sewage outfall of some 8,000 people (flow about 1,300,000 l/day). Here, the writer co-operated with P. A. Yeomans in designing 'wildlife' and biologically-oriented sewage lagoons, which feed hundreds of wildfowl, and then discharge to keylined fields, deep-chiselled as absorption filters, thus removing the taint of black-water residues and excess nitrates from the run-off.

All sensible town sewage treatment from flush toilets must follow the same path—first to primary mechanical breakdown and the removal of solid wastes; second to methane, third to a trickle filter; from there to lagoons and finally to soil absorption before being turned back to the stream.

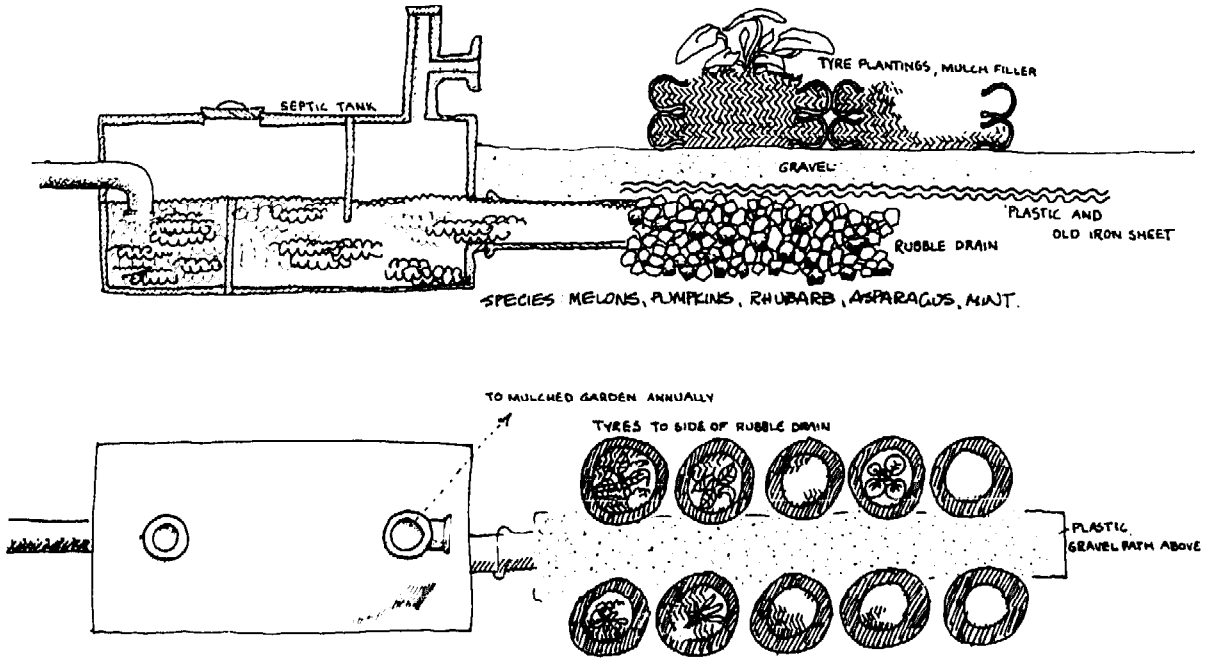


FIG. 6.20: DISPOSAL OF SEPTIC TANK EFFLUENT OR SULLAGE VIA TYRE-PLANTED ROWS.

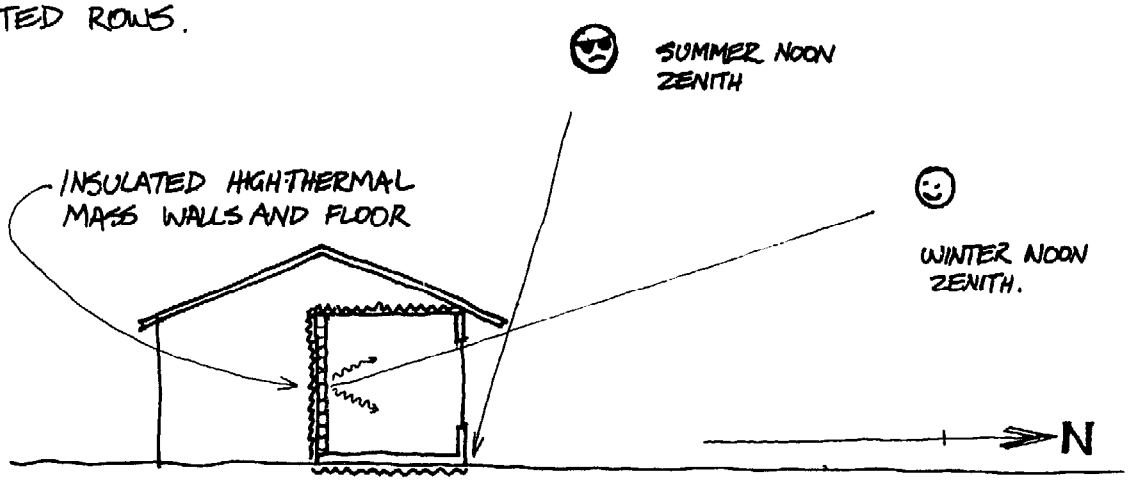


FIG 6.21: SUN/WINDOW/EAVE RELATIONSHIP.

WATERWORKS 7

AQUATIC POLYCULTURE 7·1

Rather than attempt a species design for aquaculture, I have concentrated here on both broad and detailed construction designs, so that people might extract from these for their own sites, and (hopefully) public authorities may reform their simplistic approach to impoundments by the modifications suggested in figs. 7.7, 7.8 & 7.9.

My own inclination is to attempt a 'wild' water polyculture, and observe the result. The essential elements (selected for local climate) are:

- mussels in pond bottom mud;
- eels (if naturally present) in tyre refuges;
- a browsing fish for algae;
- a predator fish screened off (as per Fig. 7.12);
- crustaceans as shrimp, crabs, marron or other useful species in brush pile refuges;
- insect attractants as flowering verge plants (Buddleia, ti-tree, herbs), lights over pond at night, and hide or meat baits over water for flies;
- small local fish (pygmy perch, galaxids, minnows) for mosquito control;
- shallow edge plants of tall rush or wild rice as frog and bird refuges;
- lawn edge for grazers such as geese and swan;
- islands for breeding waterfowl and protection from foxes;
- nestboxes for wildfowl;
- some raft culture of plants;
- floating aquatics such as water chestnut (*Trapa*);
- edible root species, such as the water lilies, lotus, or water chestnut (*Eleocharis*) as underwater tyre plantings;
- stabilization of banks by stepped log, tyre or hand-cut planted ledges, using bamboo, pampas or such shallow matted-root species;
- seepage planting of fruit or nut tree species (cherry, walnut);
- local plantings of watercress, mint; and
- trials of a variety of spawning 'bottom' materials.

Observation of this sort of polyculture will reveal management problems and solutions, enabling the owner to strengthen successful techniques and species. Thus this section has more illustrative than documented material. The field of complex aquaculture, including mariculture, awaits local trials, which we at Tagari hope to implement in the near future.

The natural cleansing processes for water are suggested in Fig. 7.11, where various biological filter systems are used for recycling water from still ponds, or cleansing water from polluted outlets.

WATERWORKS CONSTRUCTION 7·2

For dam and channel construction, one can do no better than to read Yeomans[2], who diagrams and explains the construction of large farm barrage, contour, and storage dams. These are, however, not specifically designed for any but water storage and reticulation in the Keyline system, and several additional features can be added for polyculture considerations.

Combined, Keyline and permaculture would seem to have achieved a rare conscious integration in water and soil treatment *plus* integrated biological planning. Such combinations give pleasure on small-holdings of from 1-15 acres, but would ensure stability for any country which applied them on a national scale. In Australia, the most humble dwelling must be 'approved', but men can use thousands of acres in a delinquent manner, subject to no higher authority than their own stunted intellect, or the profit motive.

7.2 Some modifications to very large storage waters are given here (Fig. 7.3) but the main modifiers to farm dams are these:

- island refuges for breeding waterfowl;
- shallow shelves for waterfowl forage plants, at the rear and edges of large dams;
- deep sump refuges for fish in areas where the dam is less than 10 feet deep and where summer temperatures are high;
- peninsula structures, with or without a moat, for house fire-protection in fire-critical areas; and
- south banks to site plants, houses, glasshouses (to gain reflected heat benefits in winter and at low sun angles).

Some of these features are illustrated in Figs. 7.3 and 7.13.

1 Nomenclature of Ponds and Lakes

Some nomenclature of man-made waterworks is necessary to understand the figures and systems outlined. I have in part followed Chakroff[16] and Yeomans[2] here. Briefly the names of larger impoundments are:

Barrage ponds: are across stream courses, filled directly by the stream, or by valley run-off. (Figs. 7.1 & 7.2)

Diversion ponds: are filled by a diversion channel, which leads water from stream or run-off area such as a bare, rocky slope. (Water is diverted from its normal course.)

Ring Dams: (or "Turkey nests" in Australia) are flatland storages above grade. Water must be pumped into these, and they form one of a series of:

Storage ponds: steady level ponds formed as barrages, which take water from upstream barrages, and lead it into contour channels or irrigation banks. These are known as penstocks in hydro-electric schemes.

Contour dams: walls made along a contour, with wing banks running upslope to impound water. The contour may be concave or convex on the downhill side. (Fig. 7.4)

All of the above, (with the exception of penstocks) are normally subject to fluctuating levels as water is used up below them.

Water storages for growing fish and plants, are, in the main, very differently designed structures than are those (now very plentiful) for stock watering or irrigation alone. For instance, many small ponds of from 100 m² to 500 m² (less than ¼ acre) are better suited to fish culture than very large storages of 400 m² (1 acre) or more. Graded bottoms of from 75 cm to 2 m depth suit many fish, while storage ponds for water need to be 3-6 m deep to be worthwhile on large acreages.

In deserts, even tiny rockholes may be critical for the survival of quail chicks and desert animals, (see Fig. 5.14) while relatively vast grazing shallows are needed by swan flocks in estuaries, and so on. Designers frequently overlook the biological importance of small structures, some of which are figured here as filter channels, quail ponds, or solar ponds, and engineers seem little concerned with subsurface dams and shoreline or perched impoundments critical to the survival of fish. Consequently we have vast and expensive lakes for power generation, of very poor biological productivity.

Overflows are piped or boxed screens to keep fish ponds at constant level. (Fig. 7.15)

Spillways are channels that lead floodwater out of dams to streams or irrigation ditches. (Fig. 7.1)

Irrigation channels are banked drains with little or no slope, fitted with water-gates, or siphoning, or pumped to fields. They lie below water storages of all types, or lead directly off streams as diversion channels.

Steering banks are very low earth banks, sometimes only a few inches high, which are made directly downhill from irrigation channels, or border a field, so that irrigation water forms a sheet on the land. (Fig. 7.14)

Bunds are level banks on flat or graded, or walled land, such as rice paddies, which hold water for a while on crops needing saturated or very wet soils.

Perched ponds are small settling, filter, or frog ponds perched above larger storages. (Fig. 7.7)

Subsurface ponds are walls under water at full storage, but which cut off and preserve shore of estuarine water in draw-down of large impoundments (Figs. 7.8 and 7.9).

Earth tanks for stockwater, are excavated *below* surface level. (Fig. 7.6)

In biological terms, we can also add the fish ponds:

Brood ponds (for adult breeders). *Spawning ponds,* and *Nursery ponds.*

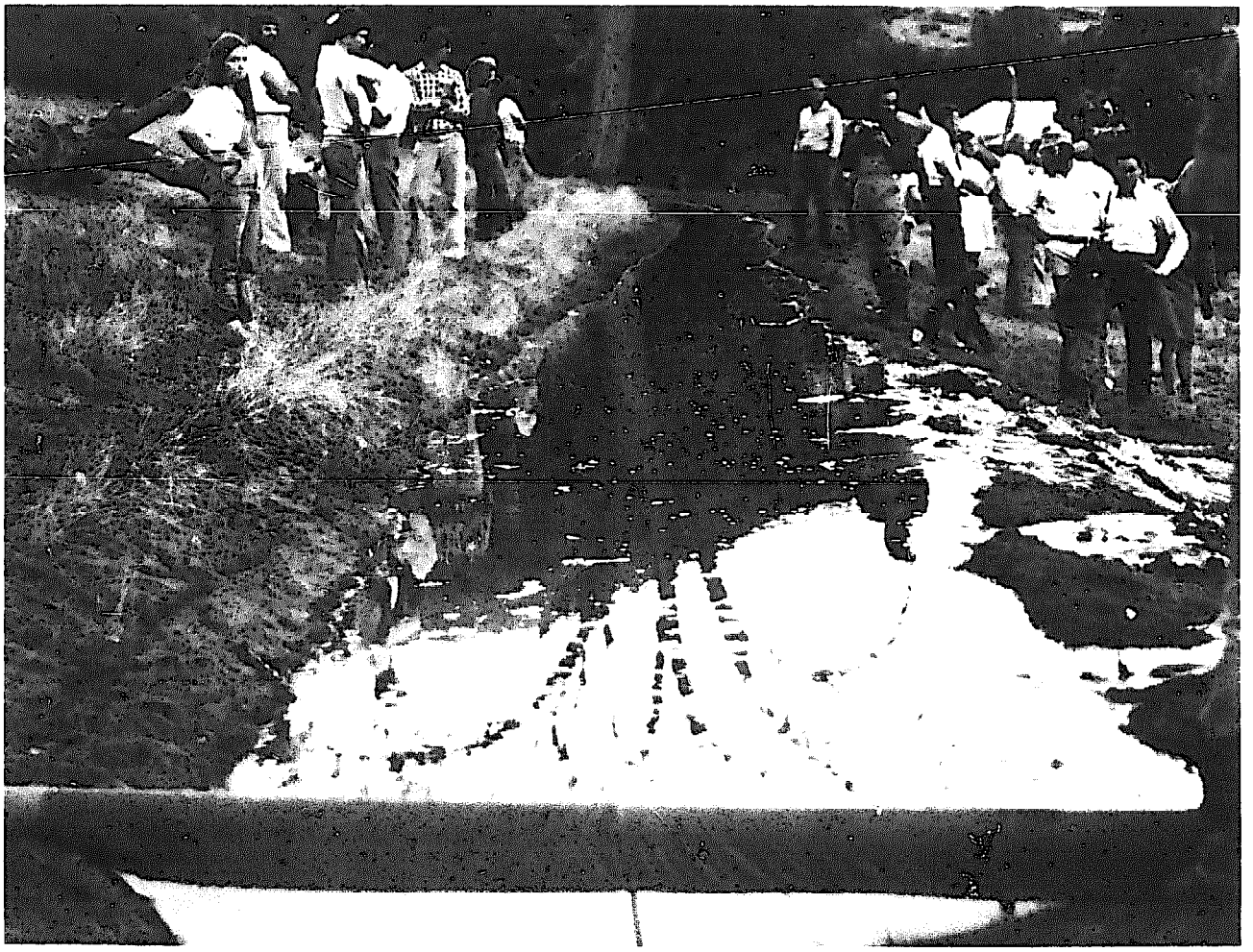
Solar ponds are used specifically to produce heat. (Fig. 7.10)

Dew ponds are constructed to catch night moisture.

A particular problem in many granitic, sandy, or shaly sites is the "dry" dam, which leaks through the base and walls. Such failures were "cured" in the old days by a variety of means, ranging from "bumping" the walls with from 1-3 plugs of gelignite when the dam filled after heavy rain, using lime and gypsum to seal cracks, and feeding cattle or sheep in the dry pond with bales of hay. The latter solution came very close to the modern Russian development of gley (pronounced 'glee). Gley is used in sandy, gravelly, stony or fissured soils where water will not lie.

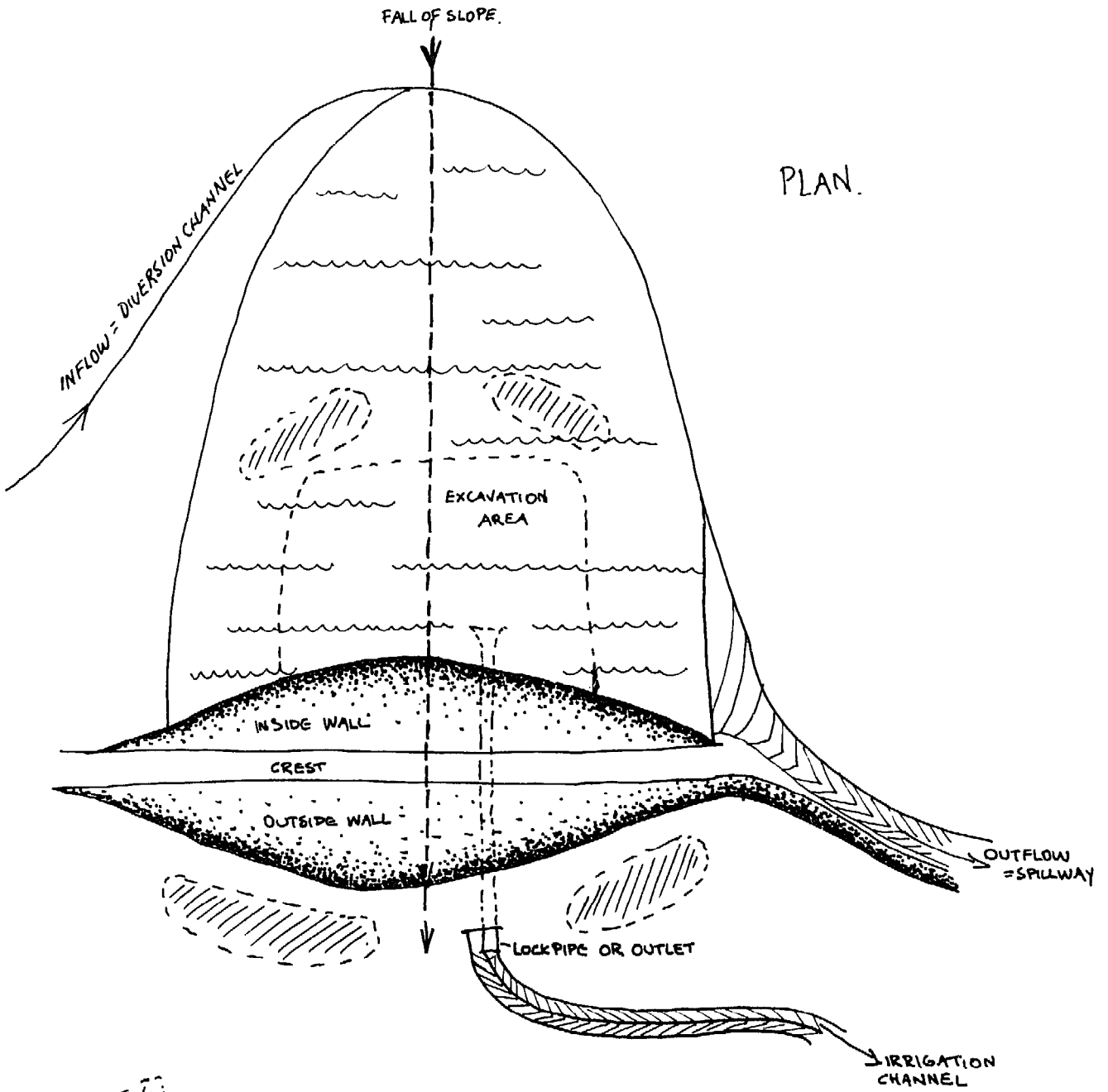
To gley a pond (after Chakroff[16]):

1. Clear pond bottom of all debris and rocks.
2. Lay fresh cow or pig manure, green lawn or lucerne clippings evenly at 75-100 mm deep.
3. Cover with paper, cardboard, plastic, old carpet, hay, leaves, grass etc. completely.
4. Put weight layer of sand, soil, clay over.
5. Wait 2-3 weeks for ferment in base layers, and fill pond.



AT KIEWA (WALLACE FARM). IRRIGATION CHANNEL, BLOCKED WITH A CANVAS 'FLAG'. WATER SPILLS OVER INTO A CHISELLED FIELD.

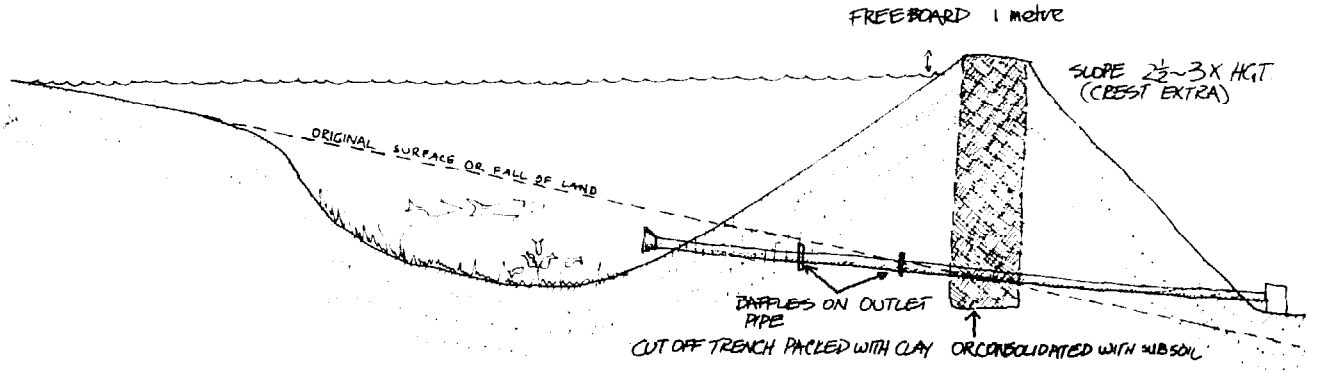
PLATE 7·1



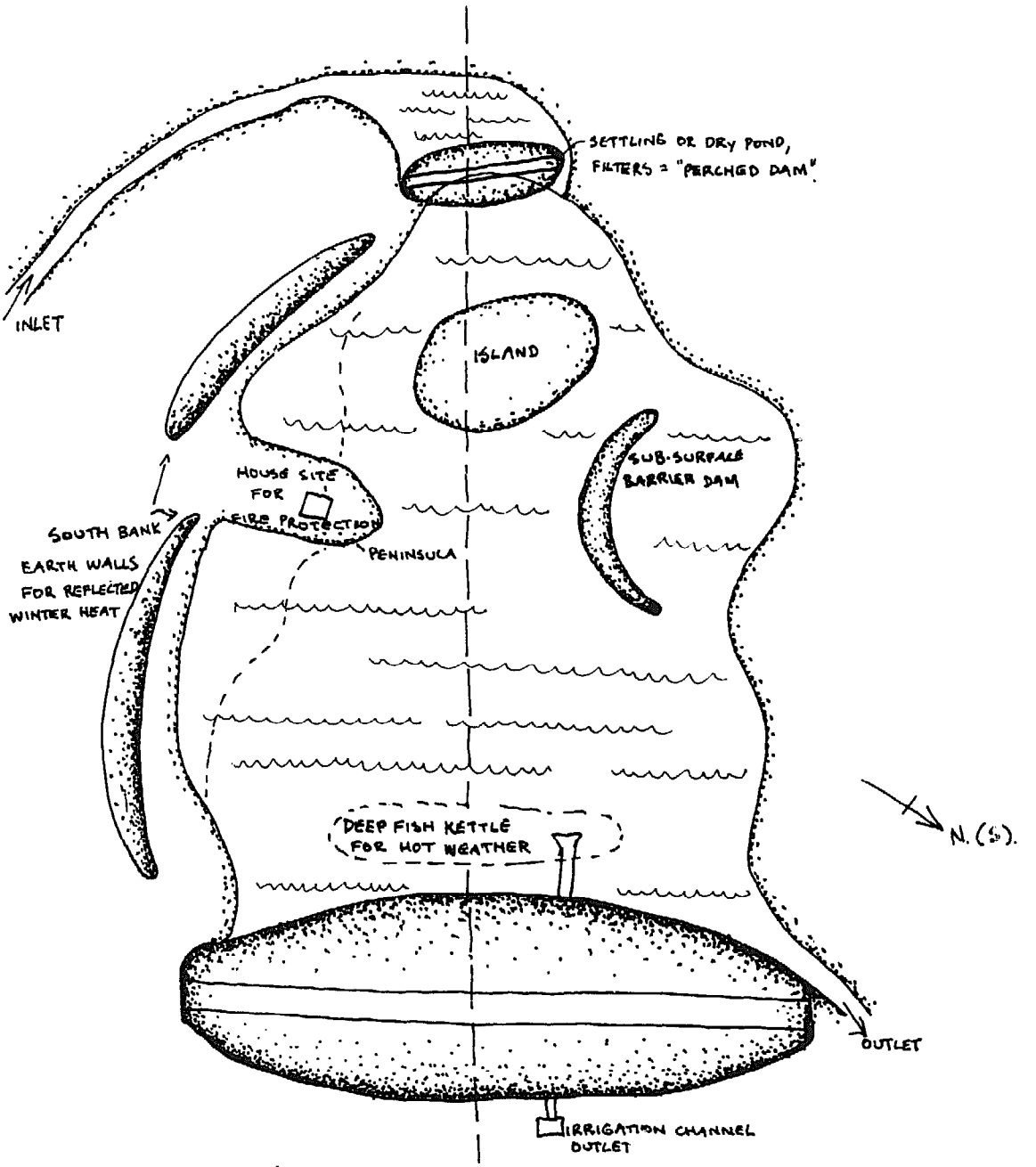
- TOPSOIL STORED DURING CONSTRUCTION, LATER SPREAD 2" THICK ON DAM WALL.

'CREST' - IS ALSO SITED ABOVE THE CUT-OFF TRENCH AT THE BASE OF THE WALL, PACKED AS A 'KEY' WITH CLAY.

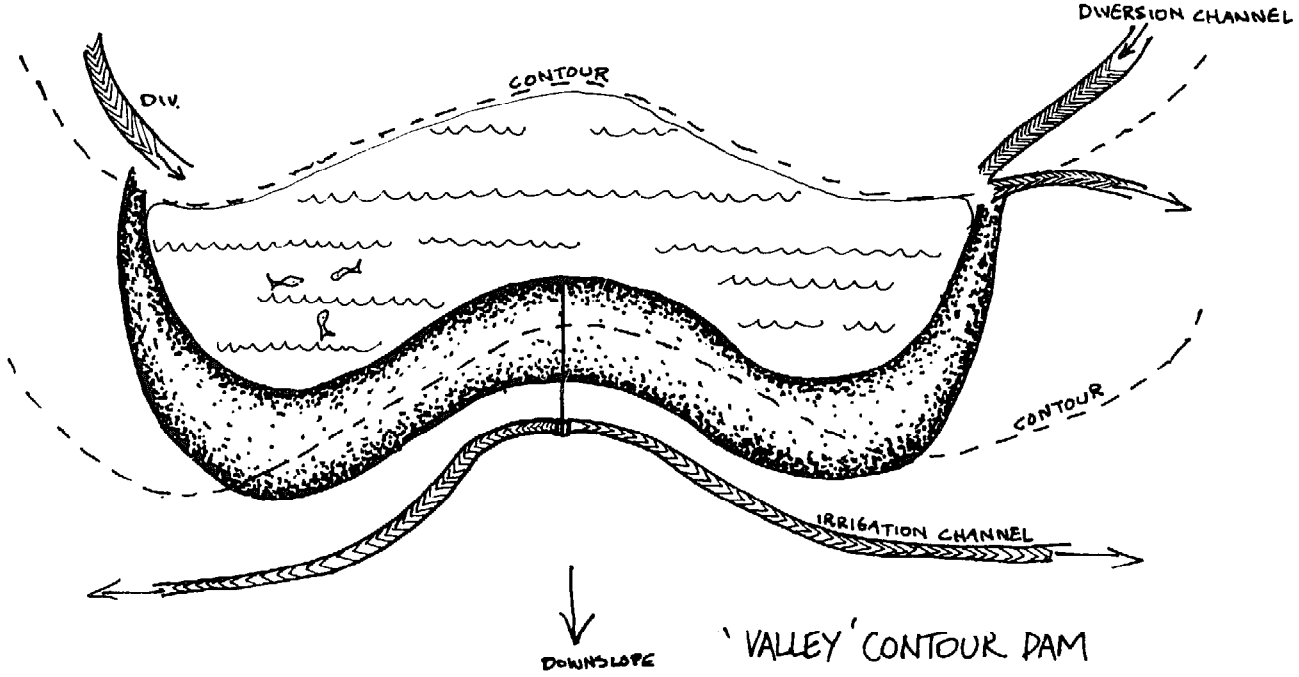
FIG. 7·1: A CLASSICAL BARRAGE DAM (AFTER YEOMANS[2]). PLAN


FREEBOARD 1 metre
SLOPE 2½~3X HGT (CREST EXTRA)
ORIGINAL SURFACE OR FALL OF LAND
BAFFLES ON OUTLET PIPE
CUT OFF TRENCH PACKED WITH CLAY
OR CONSOLIDATED WITH SUBSOIL

A CLASSICAL BARRAGE DAM (AFTER YEOMANS[2]). SECTION. FIG. 7.2:



POSSIBLE "COMPLICATIONS" ON CLASSICAL DAM, FOR PERMACULTURE PURPOSES. FIG. 7.3:



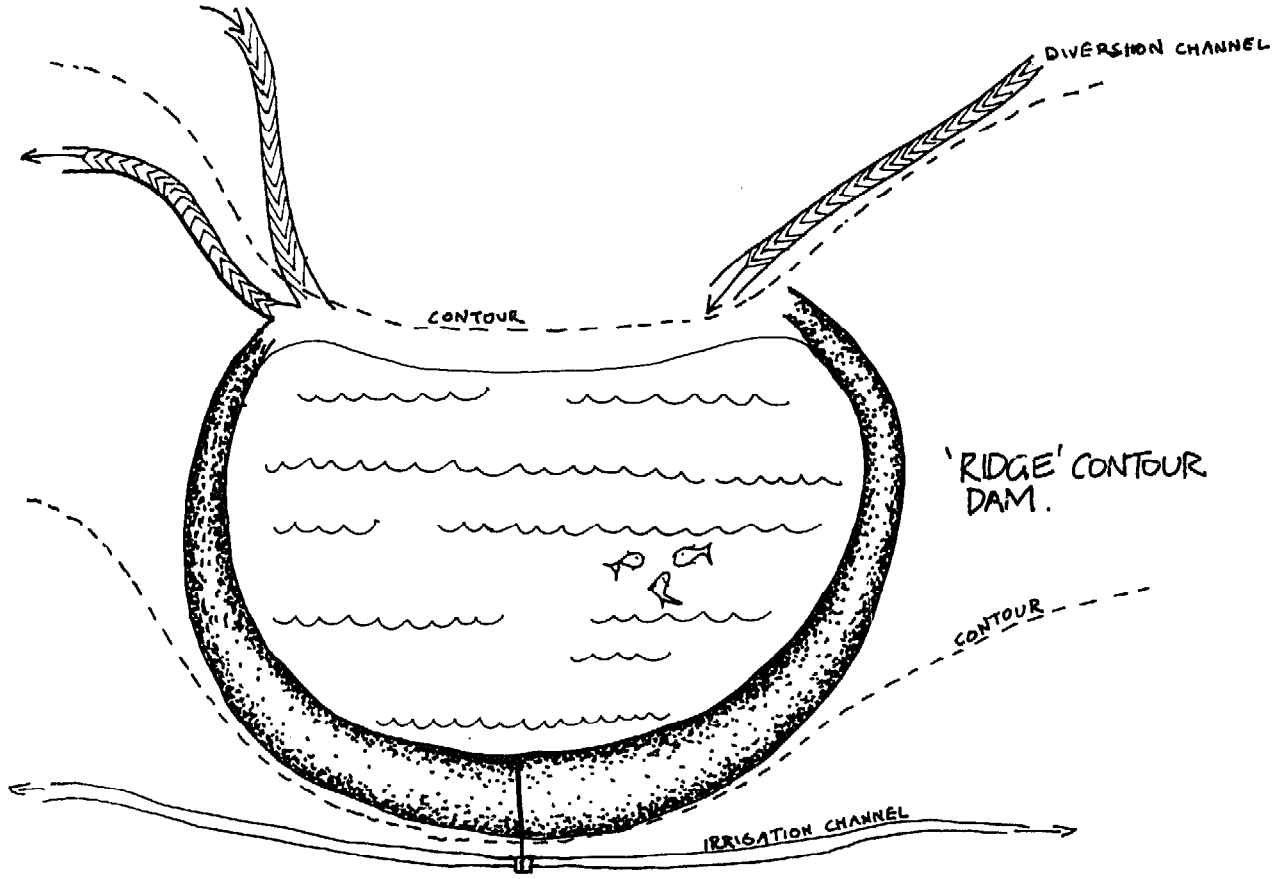
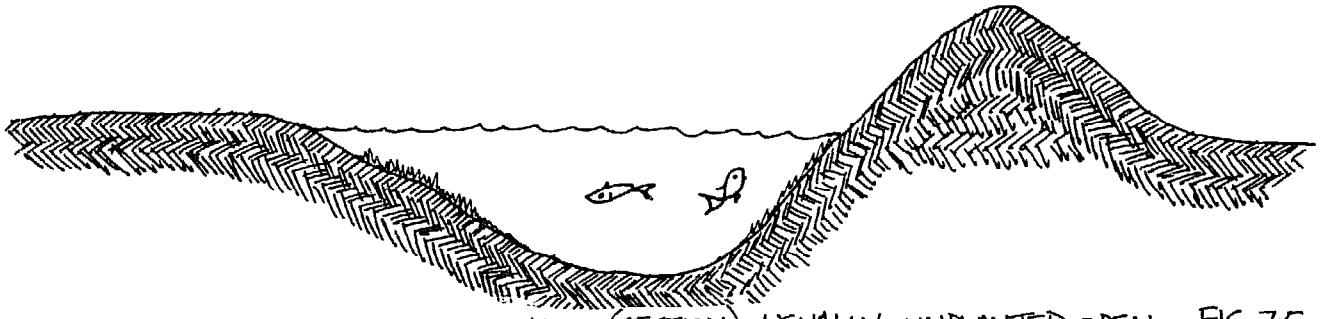
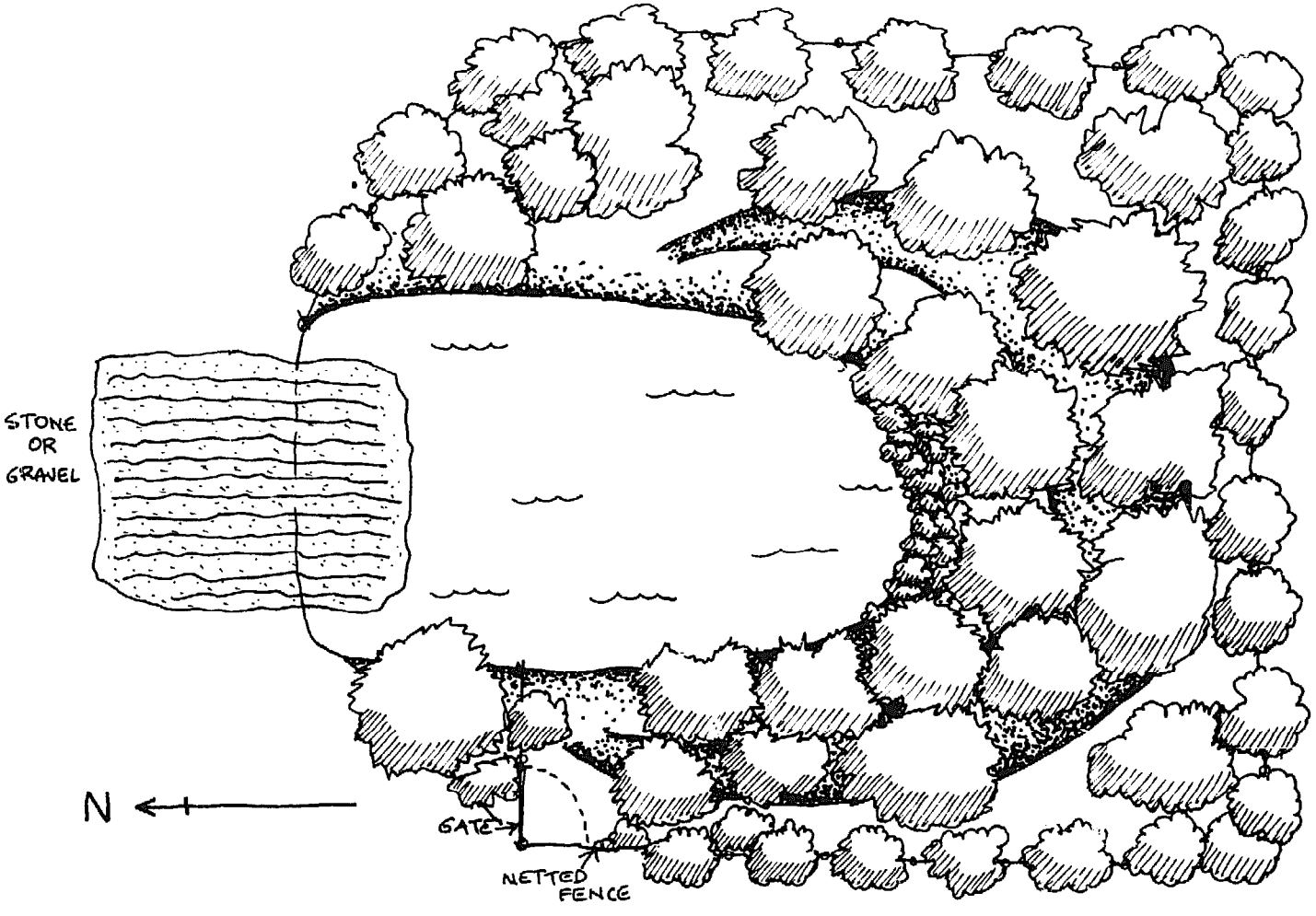


FIG. 7.4: CONTOUR DAMS.



TYPICAL EARTHBANKS OF FLATLANDS (SECTION). USUALLY UNPLANTED, OPEN TO WIND AND EVAPORATION. OFTEN WASTE SUBSOIL IS HEAPED ON THE SUN SIDE AND STOCK CAN APPROACH FROM ANY QUARTER MUDDYING WATER. FIG. 7.5



PLAN OF 'REFORMED' EARTH TANKS. IF ORIENTED TO NORTH POND BECOMES HEAT AND LIGHT REFLECTOR TO FORM A HOT MICROCLIMATE WHERE SPECIES, NOT NORMALLY GROWABLE IN THE AREA, WILL GROW. FOR EXAMPLE AVOCADO IN A COOL TEMPERATE ZONE. FIG. 7.6

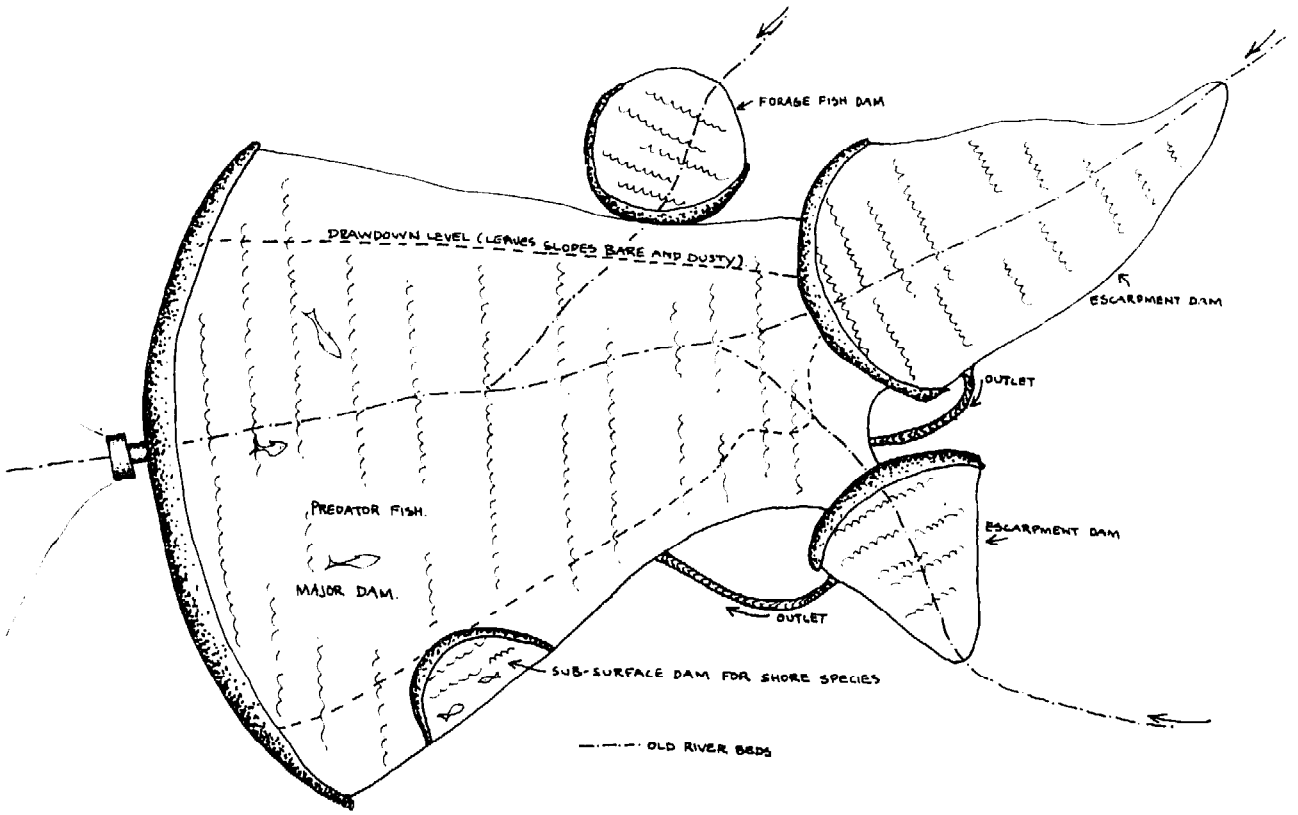


FIG. 7.7: "PERCHED" DAMS AT EDGES OF MAJOR IMPOUNDMENTS. AT DRAWDOWN LEVEL, THESE RETAIN SHORELINE SPECIES, AND FORM ESCARPMENTS FOR FORAGE FISH OR FRY.

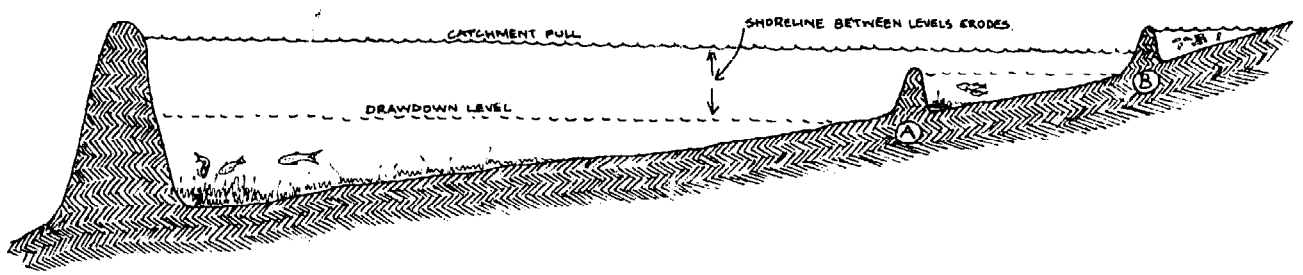
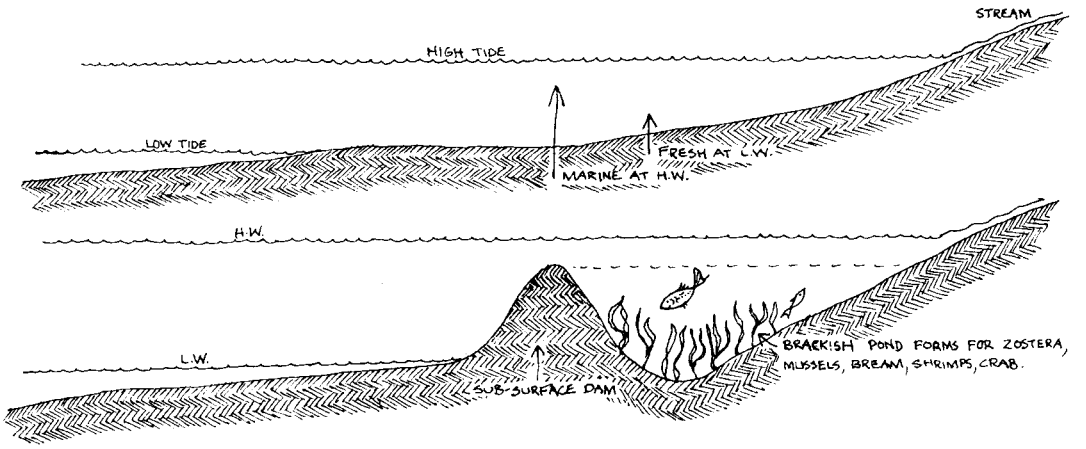


FIG. 7.8: MAJOR CATCHMENT MODIFICATIONS (SECTION).
MODIFIERS ARE A SUBSURFACE DAM TO PRESERVE AND PROTECT SHORELINE;
AND B PERCHED DAM TO BREED SMALL FORAGE FISH SPECIES.



ESTUARY SECTIONS. AREA BETWEEN TIDES PRESENTS NO NICHE FOR ESTUARINE FISH. MODIFIED AS BELOW, A RICHER RESOURCE RESULTS. FIG. 7·9

LOOKING DOWN-FLOW TO CANVAS FLAG (SEE PLATE 7·1). PLATE 7·2

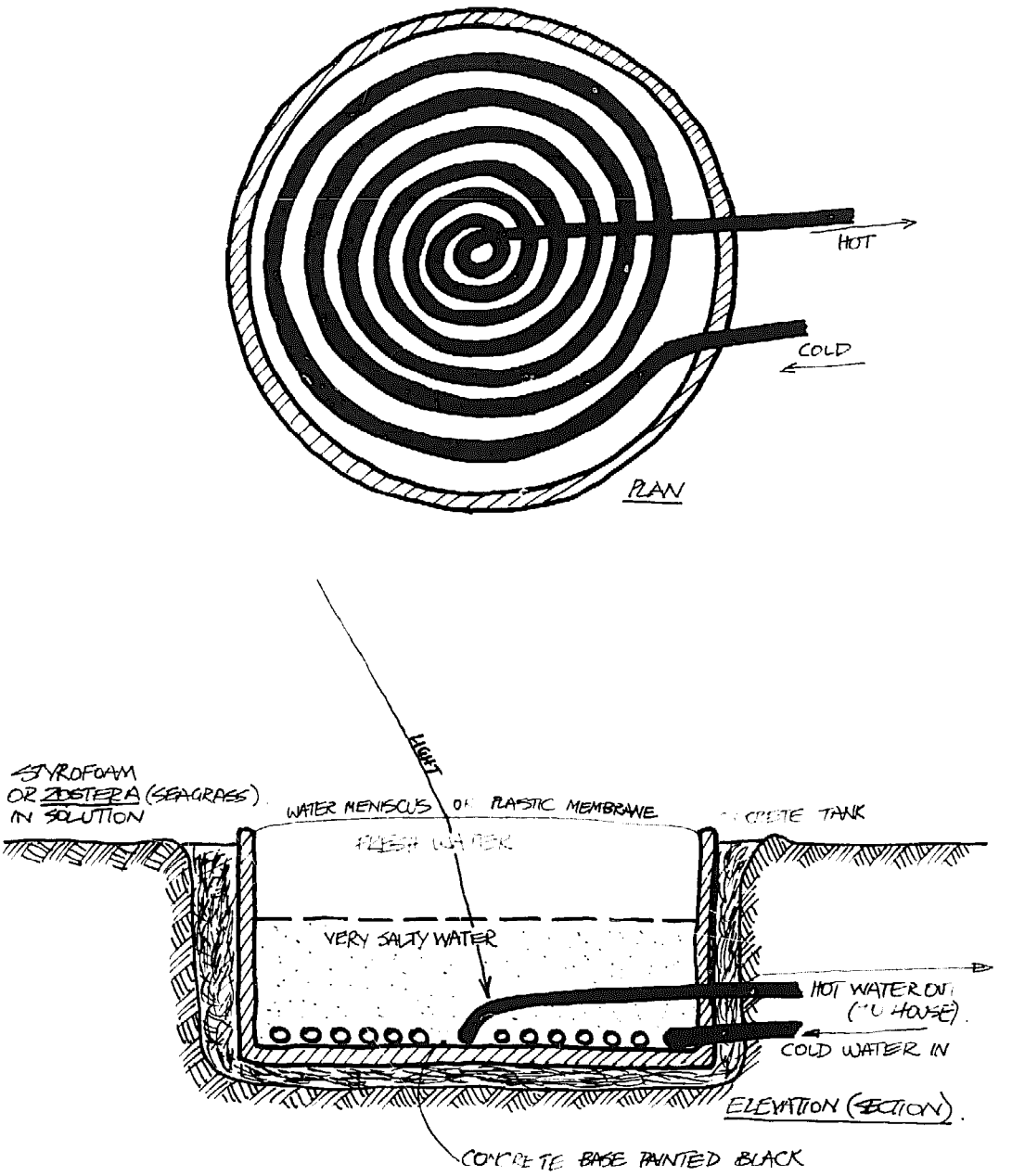


FIG. 7.10: SOLAR POND. THE SURFACE COLLECTS LIGHT FROM SKY "BENDING" IT TO FOCUS ON TIGHT-COILED PLASTIC PIPE (BLACK BEST). SALT IN WATER STORES HEAT. A MEMBRANE KEEPS THE SURFACE CLEAR (OR ADD A LITTLE FORMALIN TO WATER). WILL HEAT GLASSHOUSE, WATERTANK, HOUSESLAB, JAPANESE-STYLE BATH, ETC. (THESE PONDS OCCUR NATURALLY IN SEA-SIDE BASALT POOLS).

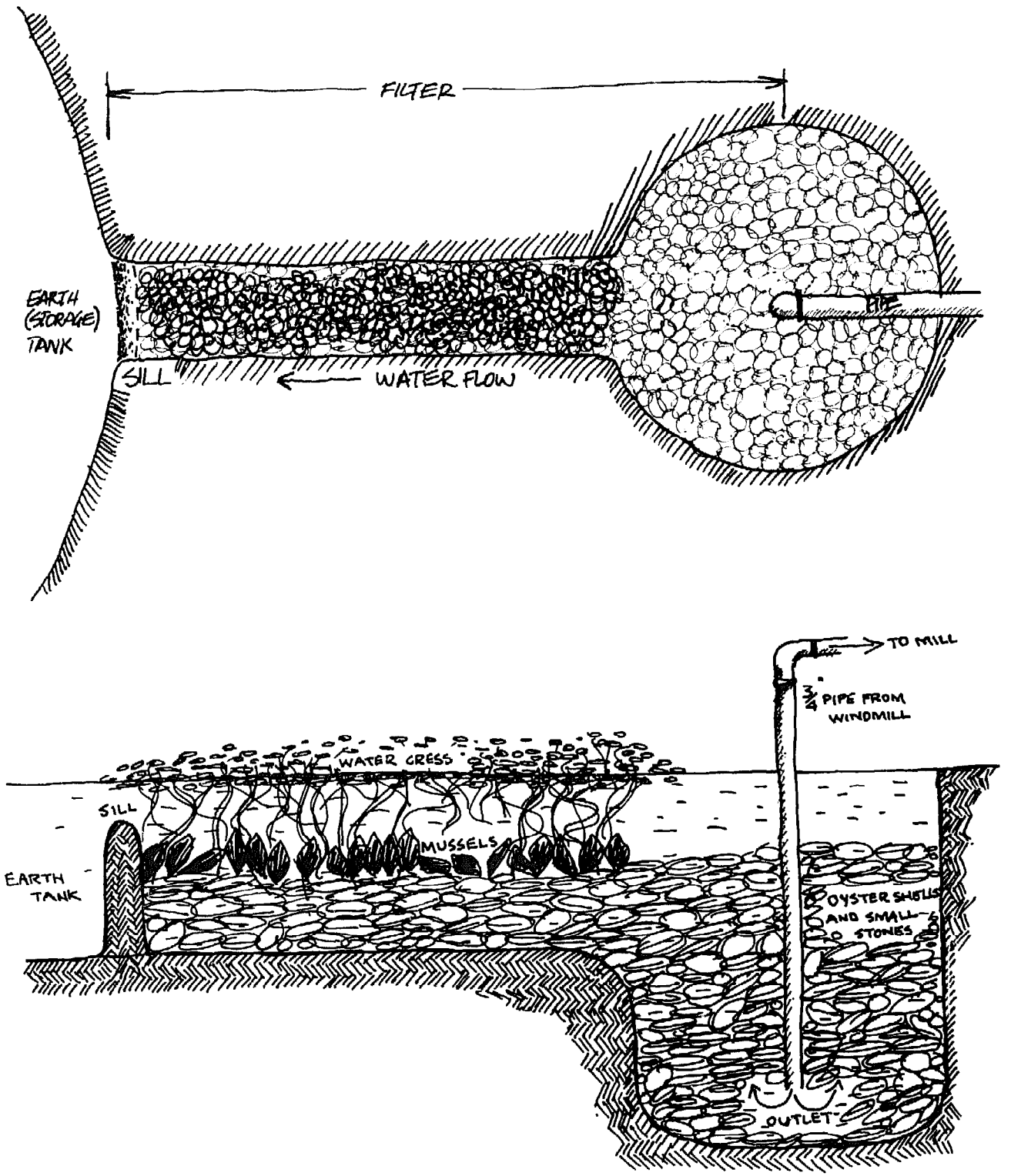


FIG. 7.11 : WATER FILTRATION. WATER FROM LOW DAM IS PASSED THROUGH A FILTRATION CHANNEL TO EARTH TANK (BIOLOGICAL FILTER).

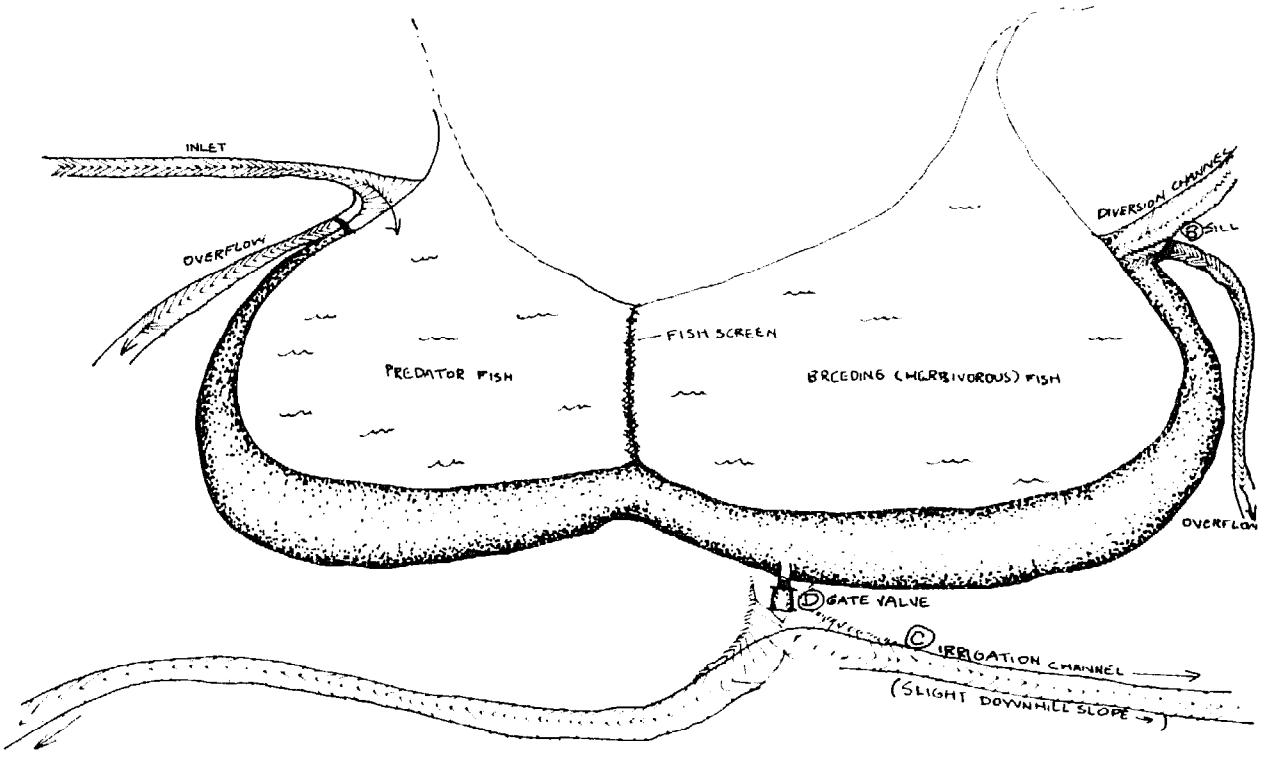
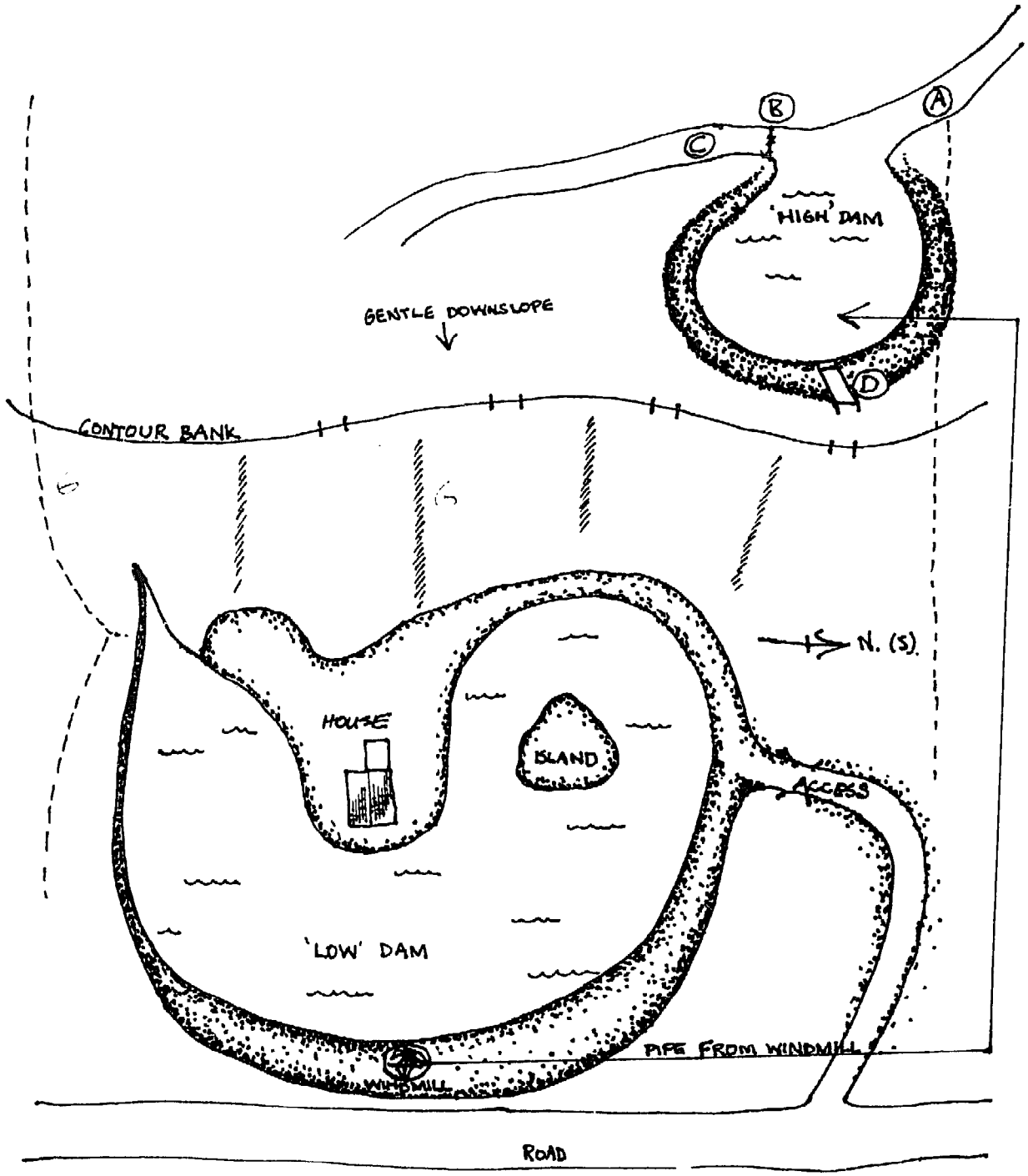


FIG. 7.12: "DOUBLE" DAM IN DEPRESSION CONNECTED VIA FISH SCREEN. PREDATORS (TROUT) KEEP HERBIVORES (PERCH) CULLED VIA FISH SCREEN (YANDOIT, VICTORIA)

PLATE 7.3: 'PERCHED' DAM ABOVE MAIN STORAGE FLOODS AT WINTER LEVEL AND IS A REFUGE FOR SHORELINE SPECIES. (McCABE FARM, KIEWA VALLEY). NOTE: SIZE INDICATED BY PEOPLE ON DAM WALL.



LAYOUT OF 5 ACRES AT DIGGER'S REST, VICTORIA. HOUSE PROTECTED FROM FIRE, WHOLE AREA WATER CONTROLLED. DESIGNED BY YEOMANS, GALL AND MOLLISON. (SEE DETAIL FIG. 7·14.) FIG. 7·13

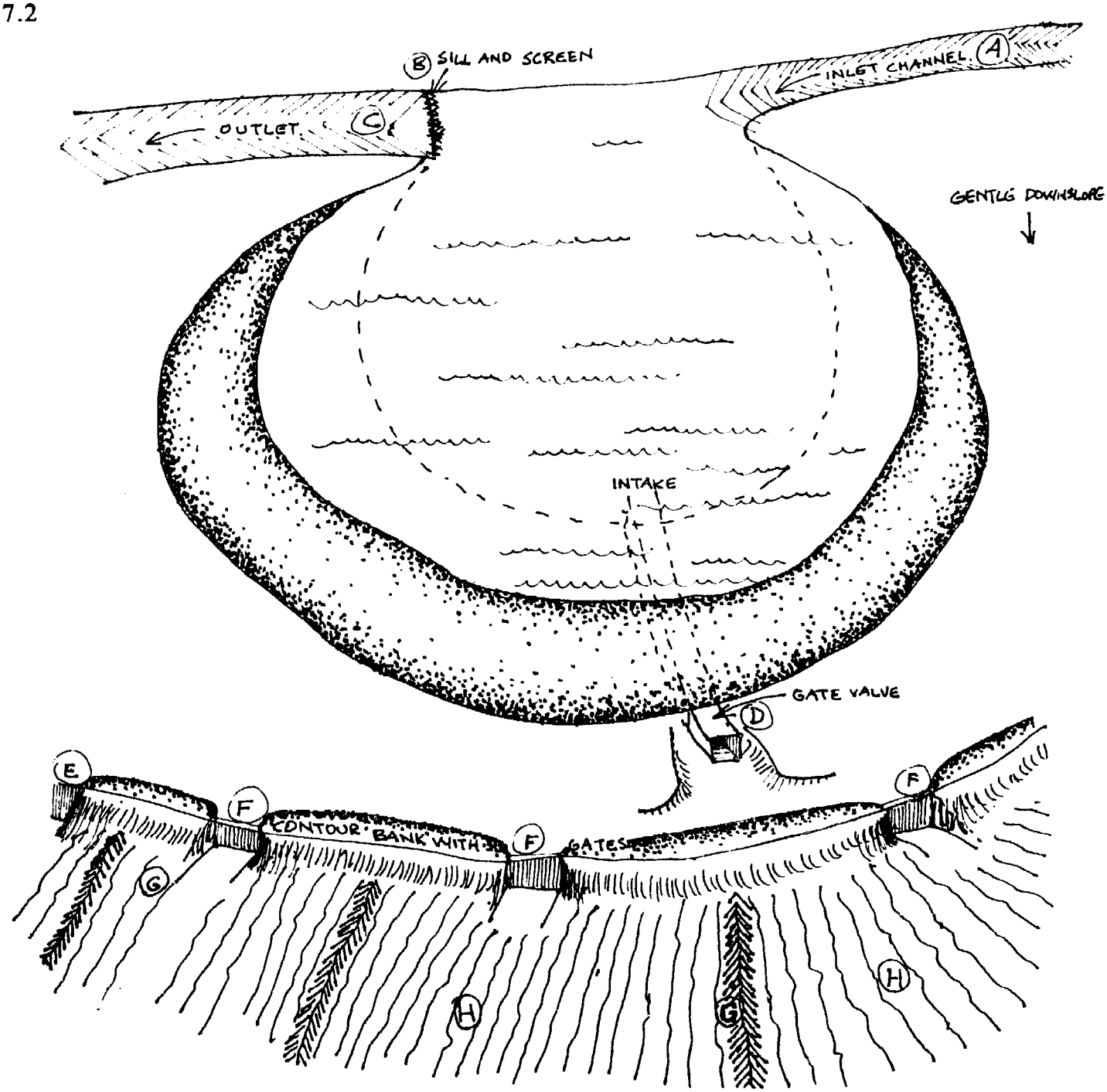
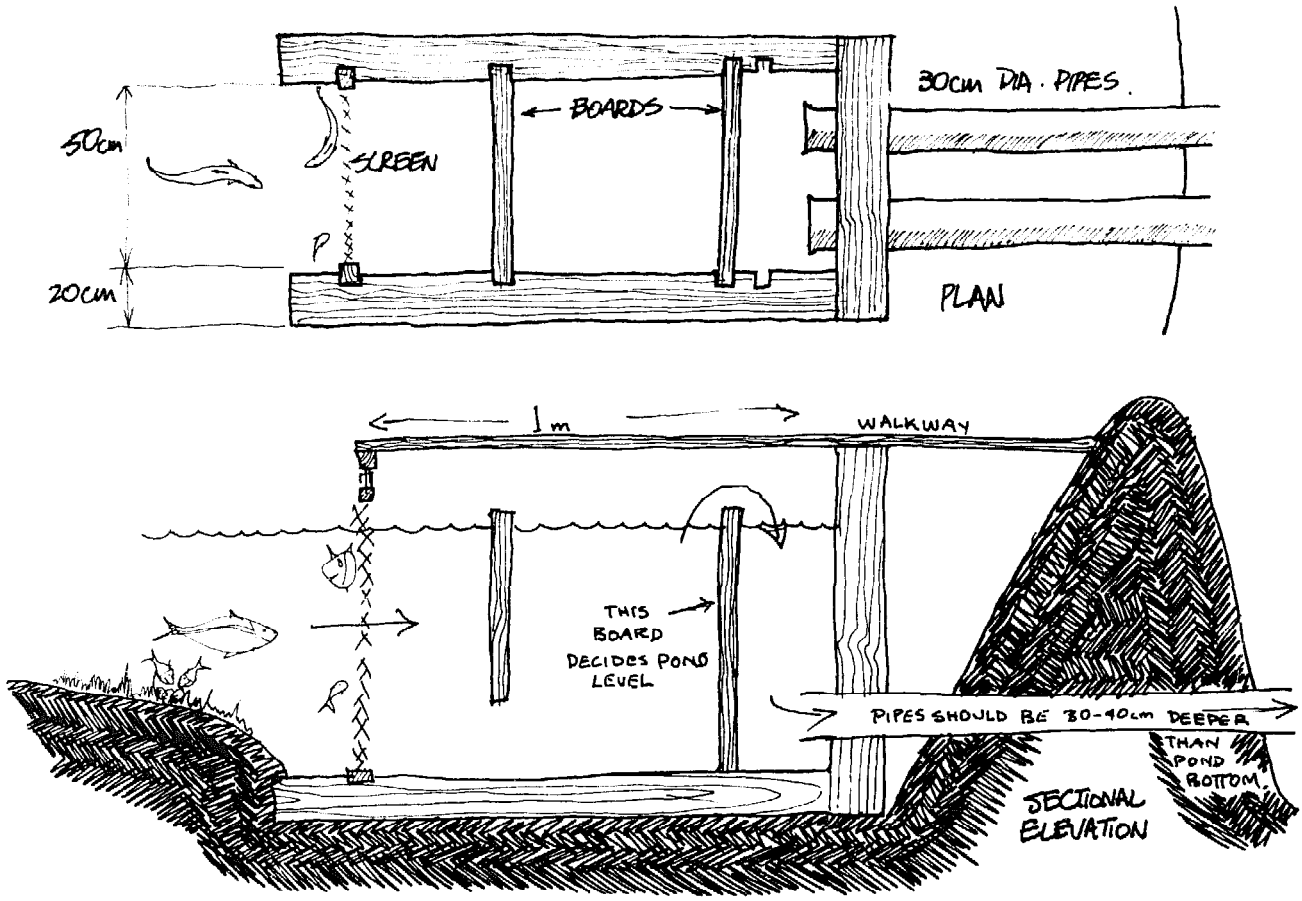
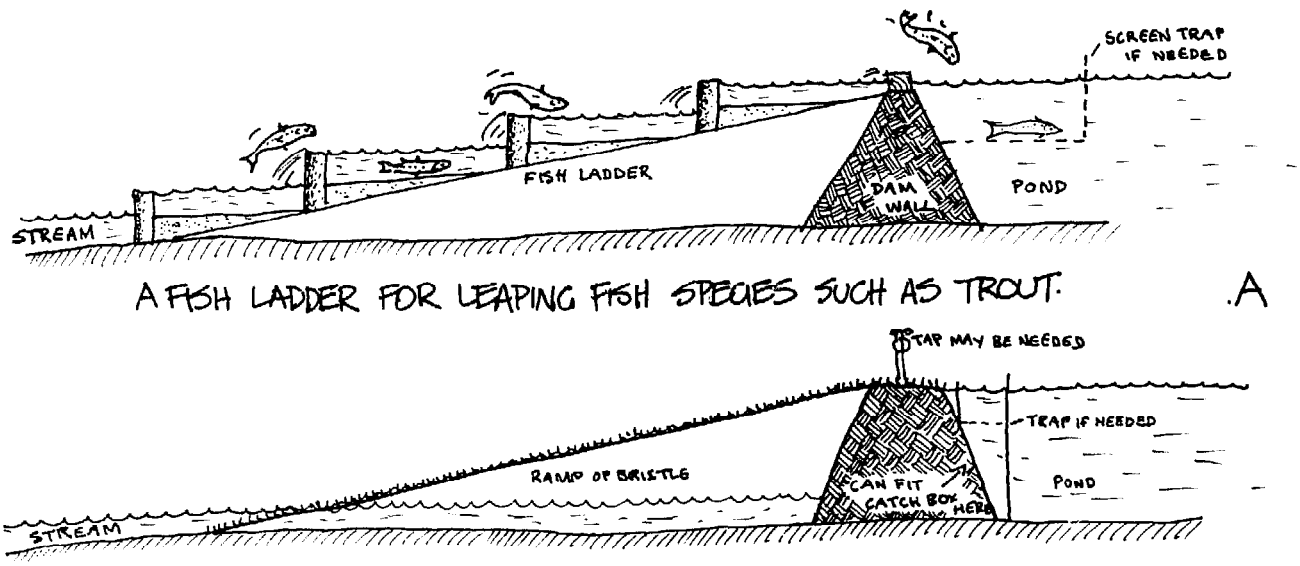


FIG. 7.14: HIGH HOLDING DAM GATHERS WATER AT (A) FROM A 1:150 LEAD IN (DIVERSION) DRAIN ACROSS SLOPE. IN FLOOD, THIS LEAD IN WATER SPILLS ACROSS SILL (B) TO OUTLET CHANNEL (C) OR CAN BE RELEASED THROUGH GATE VALVE (D) AT ANY TIME. CONTOUR BANK (E) HOLDS RELEASED WATER FOR CONTROLLED LIBERATION INTO FIELDS (H) VIA GATES (F). WATER IS THEN CONTROLLED BY VERY LOW STEERING BANKS (G), AND SOAKS INTO CHISEL PLOUGHED FIELDS. DIRECTION OF CHISELLING INDICATED BY WIDE-SPACED LINES. (AFTER DAM AT DIGGER'S REST DESIGNED BY KEN YEOMANS).



THE 'HERGUTH MONK'. CLASSICAL FISH SCREEN OVERFLOW FOR CONSTANT FLOW. FIG. 7.15

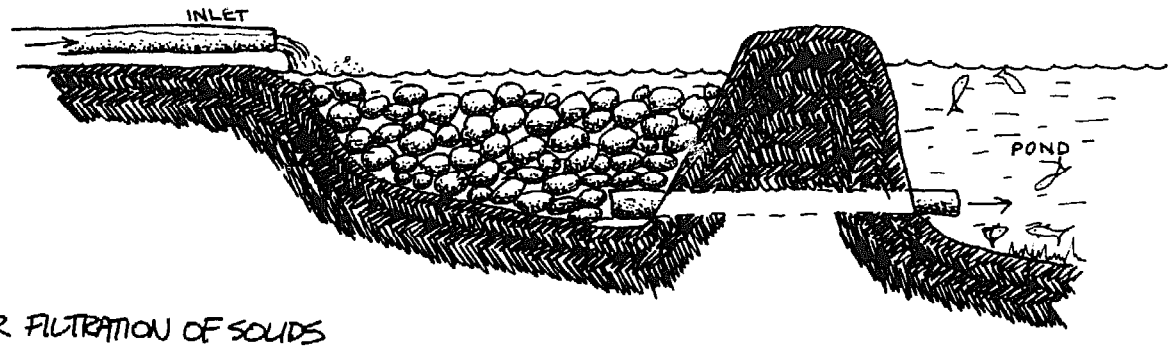


A FISH LADDER FOR LEAPING FISH SPECIES SUCH AS TROUT. .A

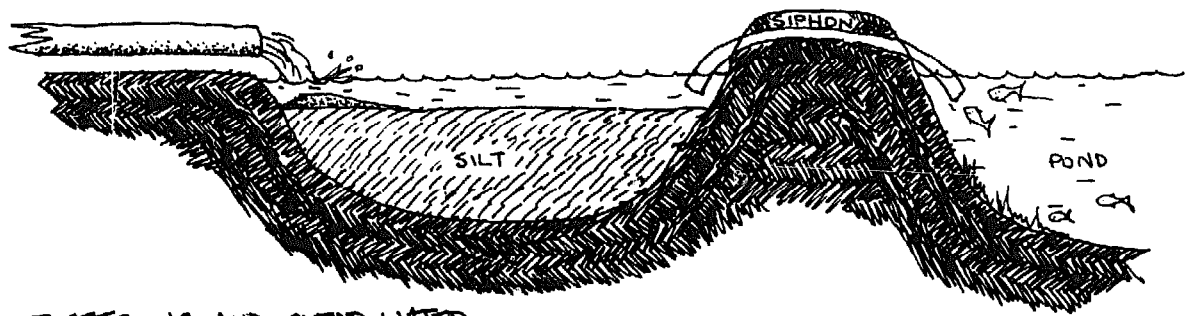
A SLOPE OF NYLON BRUSH BRISTLE, OR TURF, OR ROUGH STONE FOR WRIGGLING .B AND CREEPING SPECIES SUCH AS ELVERS, YABBIES, SHRIMPS, ETC (AFTER MODEL AT LIMERICK, IRELAND).

TWO BASIC UPSTREAM MIGRATION AIDS FOR STREAM SPECIES. FIG. 7.16

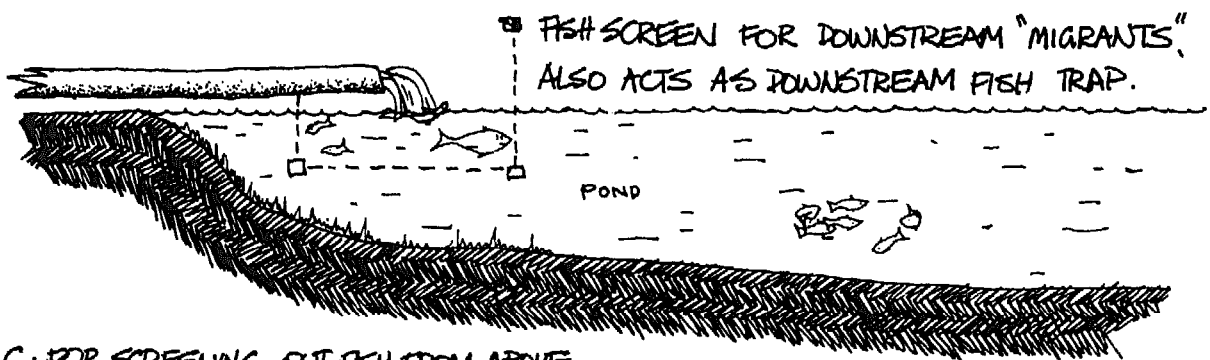
7.2



A · FOR FILTRATION OF SOLIDS

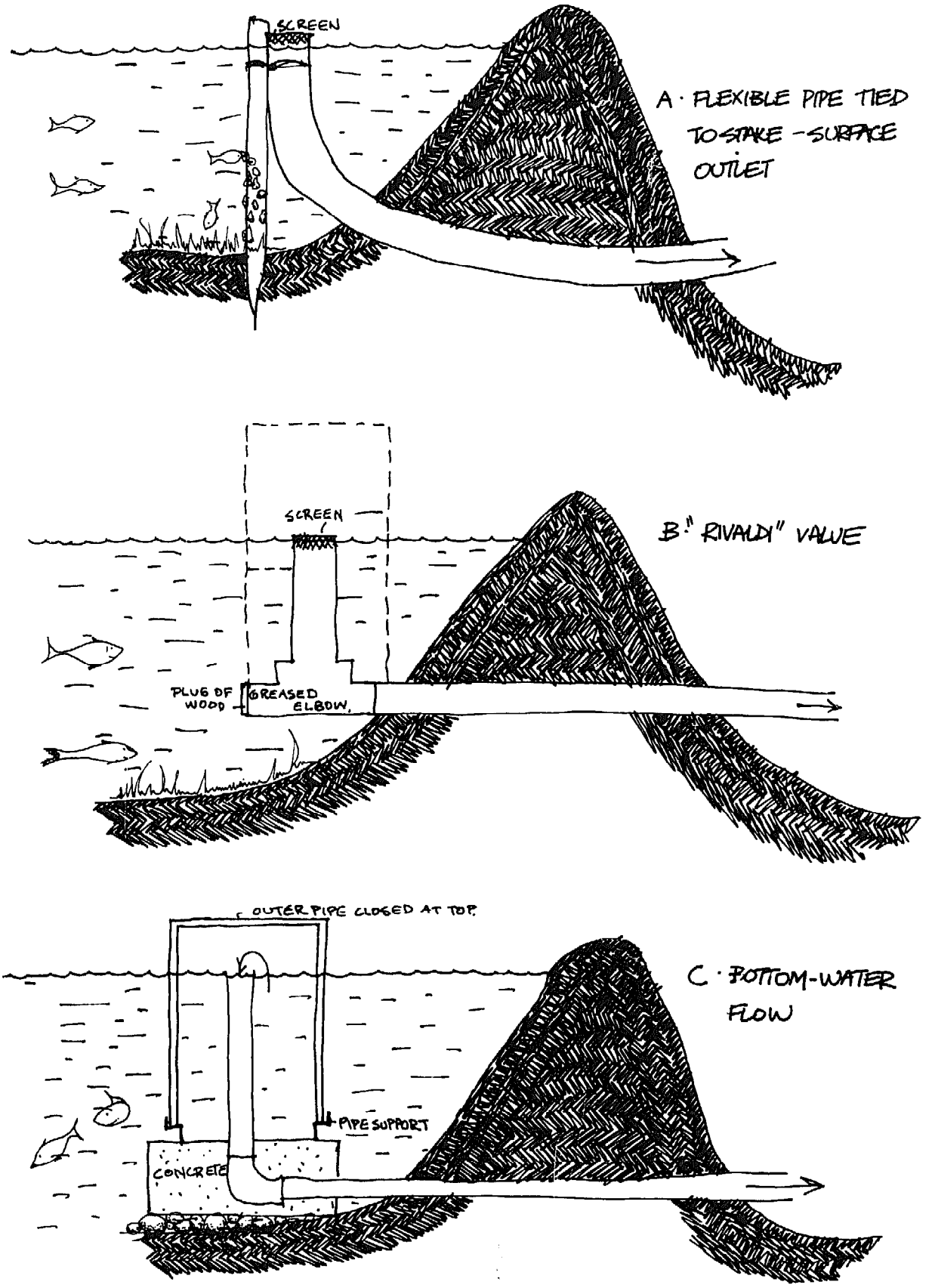


B · FOR SILT SETTLING AND CLEAR WATER.



C · FOR SCREENING OUT FISH FROM ABOVE.

FIG. 7.17: INLET TO PONDS (AFTER CHARROFF[16]).



POND OUTLET STRUCTURES (AFTER CHAKROFF[16]). FIG. 7.18

7.3 POND CULTURE

John Wood, writing in *Radical Technology* (Eds. G. Boyle & P. Harper, Penguin, 1976) makes useful reference to pond culture, much neglected by most of us in Australia. Because of the efficiency of surface and midwater phytoplankton and diatoms at the mud surface, nutrients and sunlight produce high yields in shallow-water systems (to 4.5 m in clear water, less in turbulent systems). Wood estimated yields of 3000 kg of fish, 1000 kg of crayfish (yabbies), 400 kg 'mussels' and the eggs and progeny of 200 ducks from 1 ha of pond. Mussel and duck manure are sufficient nutrient, and fish are reared on a "put and take" basis.

These yields (where achieved) are orders greater than most land yields of animal protein, but Woods makes little mention of plant yields—water chestnut as a surface crop, with floating hair-roots, and sweet rush (*Acorus*) or wild rice (*Zizania*) as edge species. Nor should we overlook the beneficial effects of ponds on nearby pecan, walnut and other "river-flat" trees, and the seepage areas, used to grow celery, watercress, and other edible species such as the mints, in abundance. Sewage water also vastly increases insect life, and so the productivity of wildfowl and fish, and yields really depend on rate of manurial turnover in the system. Sewage ponds are themselves ideal sites for breeding stock destined for transfer to clearwater ponds before harvest.

Following on the construction of a pond, a basic provision is to lime the area before filling, and Chakroff[16] recommends:

Ground limestone	1,140 kg/ha	Let stand 2 weeks
Agricultural limestone	2,270 kg/ha	then fill pond
Hydrated limestone, or	114 kg/ha	slowly.
Quicklime	200 kg/ha	

The best pH for gardens is 5.5-6.0, but for ponds 6.5-9.0 is ideal, hence lime usually needs to be added. Unlike drinking ponds, fish ponds are best if soupy green, so that a white (Secchi) disc disappears at 20-40 cm below the surface. This is achieved by manuring either with human or pig sewage, or by heavily stocking with ducks.

Coastal lagoons, however, frequently have a natural pH of between 9.0-11.0, as lime is present in sands, and care should be taken to test before adding lime. Green plants, compost, loam, ploughing in a green crop, feeding grain mashes to fish, etc. all lift pond productivity. Old ponds are best, and often have a deep mulch on the floor, but livestock pens such as pig or cow yards near fish ponds help with manurial input.

The ideal layout for ponds is diagrammed in Fig. 7.22, but in practice the amateur can buy fingerling (nursery) stock and proceed from there, or, preferably manage (by continuous harvesting) waters where pond fish breed in shallows or brush piles.

Many carp, tilapia, blackfish, perch, and bream will breed in ponds (local advice on species is best) and if kept harvested and "thinned" will produce size fish. This thinning of stock may be achieved by the agency of other fish.

With the foregoing in mind, carefully regulated, uncrowded, well-aerated, ideal temperature systems, with good light penetration and ample cover, gaining nutrients and food from surroundings, and containing many species of various use to man, give the highest yields, when well-managed and intensively cropped. The most efficient systems require high levels of technical knowledge, skill and time, but most water systems can produce excellent catch-as-catch-can food.

Thus, yield may be improved by creating the conditions of the water for greater yield. Highly intensive systems may include draining, liming, and resting some waters. Species able to exist low in the food chain can more directly utilize natural production or manured areas than predaceous species. Dry-land cropping as part of the fish crop cycle is commonly used to increase total yield, and to prevent disease transmission.

Water is a three-dimensional system, or four if flow (duration) is taken into account. By using all dimensions, aquaculture can benefit, so that many species or special structures (islands, rafts, emergent weed) are needed to use all resources.

Where capital for tanks, ponds, dams or managed streams is available, yields may be increased by technological aids to quite phenomenal levels, even if recycled water is necessary to make cur-

rent flow possible. Alternative technology may be brought into play (wind pumps, solar heaters) to make pond culture more cheaply productive, and if sound ecological principles are adhered to, costs can be reduced by thoughtful management. High density stocking requires paddle pumps for oxygenation.

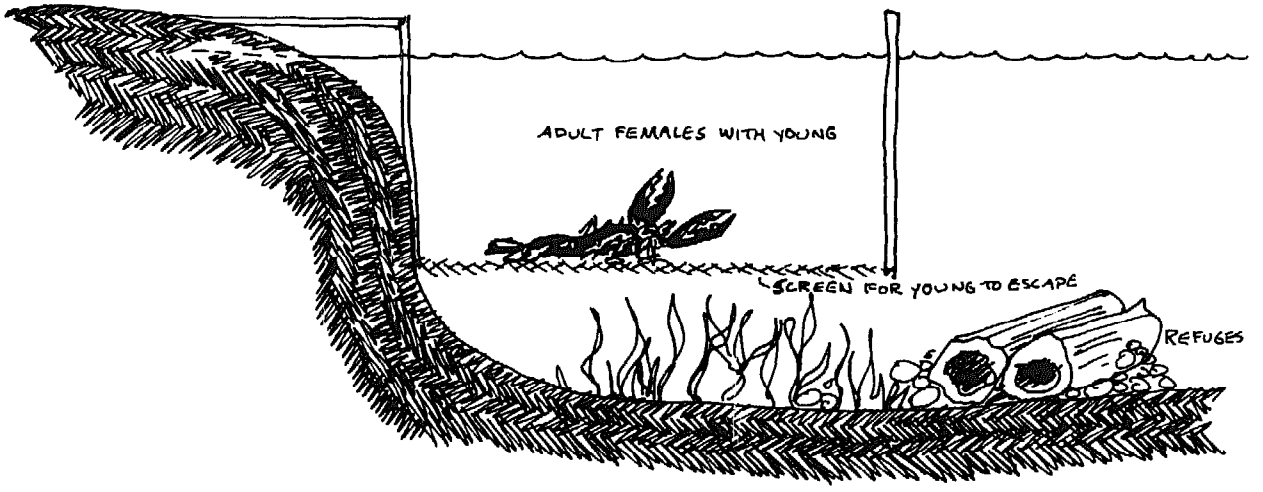
The run-off from even a modest barn roof (20 x 8 m) in a 1 m rainfall area such as Tasmania can yield 1,600,000 litres of water per annum, and 'waste' heat or manure production can be used to great advantage in such ponds. Very intensive systems call for an enclosed glasshouse situation in cool climates.

Edge and surface animals and plants (duck, wild rice) can be added to pond yield as the hedgerow adds to field yield. Similarly, drained ponds may yield rich mud fertiliser for gardens, particularly if freshwater mussels, and quick-growing plants are used to fix nitrogen in ponds.

The land-pond interchange is part of polycultural management in Asia, but is little explored in temperate zones, where marine fish were once cheap, plentiful, and unpolluted. This is no longer the case, and freshwater culture has a deservedly bright future where overfished and polluted sea species are failing to maintain their yields to man.

To briefly summarize the conditions for an effective pond culture, progressing towards more intensive production:

- small impoundments of 500 - 1000 m² (1/8-1/4 acre);
- depth of 2-5 m (7-16 feet);
- floor graded as slope to outlet;
- a mixture of fish, crayfish, plants, molluscs, waterfowl, edge plants, and land animals penned nearby;
- insect foods attracted by plants, lights, baits, colours or scents;
- adequate refuges as shallows, pipes, brush piles, logs, deeps;
- predator protection as nets or fences;
- liming and manuring as needed to pH 6.5 or higher;
- manure or waste foods added as available;
- water paddled, sprayed or stirred, or filtered and recycled as food input and stocking rates increase (to keep up the oxygen level);
- special invertebrate food ponds nearby (to breed worms, insect larvae, frogs, etc. for fish food);
- special crops grown for fish food (mainly cereal or tree crop); and
- enclosure of pond in glasshouses as a final intensive ploy (see the work of the New Alchemists in *Radical Technology*, Boyle & Harper (eds), Penguin, Hammondsworth, 1976).



SPAWNING BASKET FOR FRESHWATER CRUSTACEA CARRYING EGGS AND YOUNG UNDER TAIL (YABBIES, CRAYFISH, LOBSTERS). FIG. 7.19

7.3

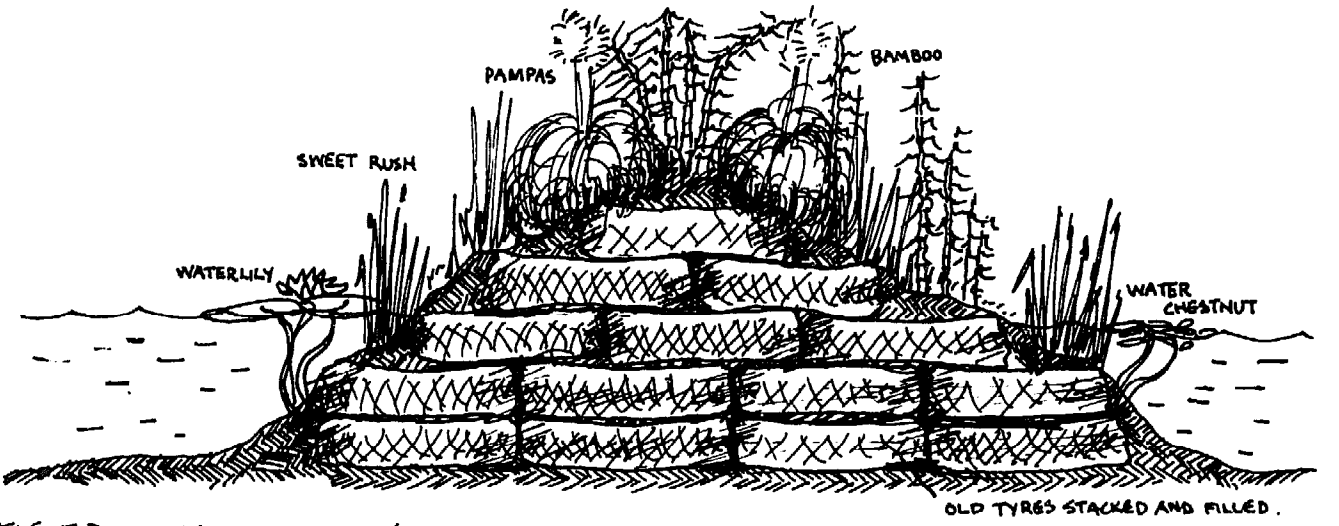
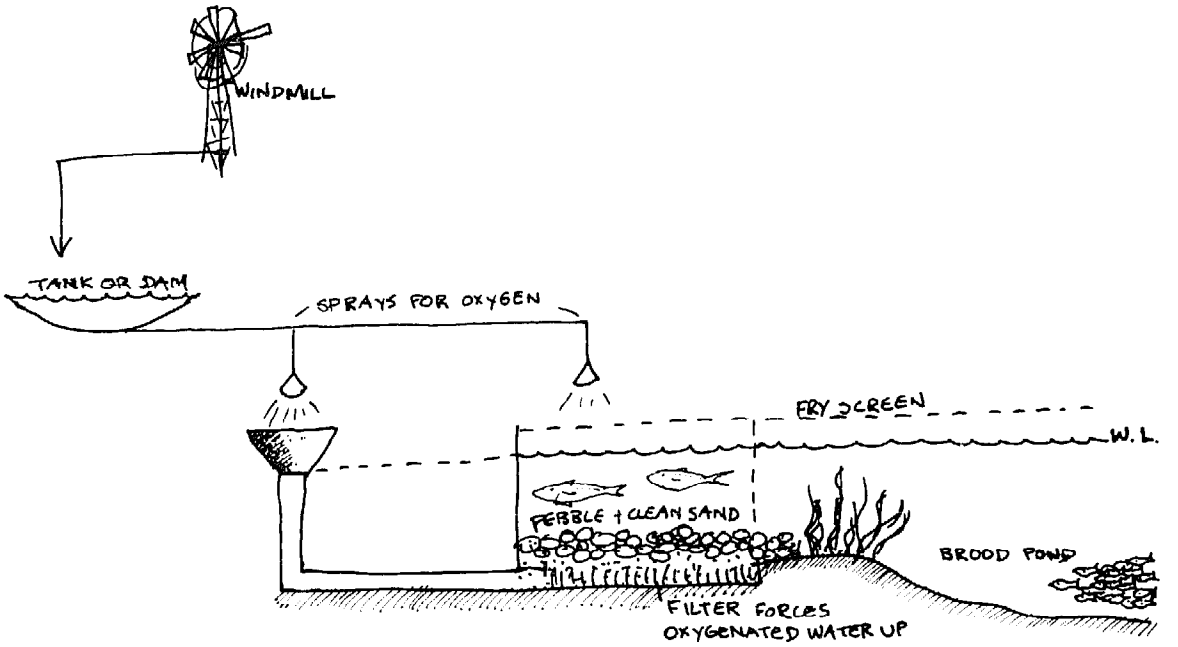
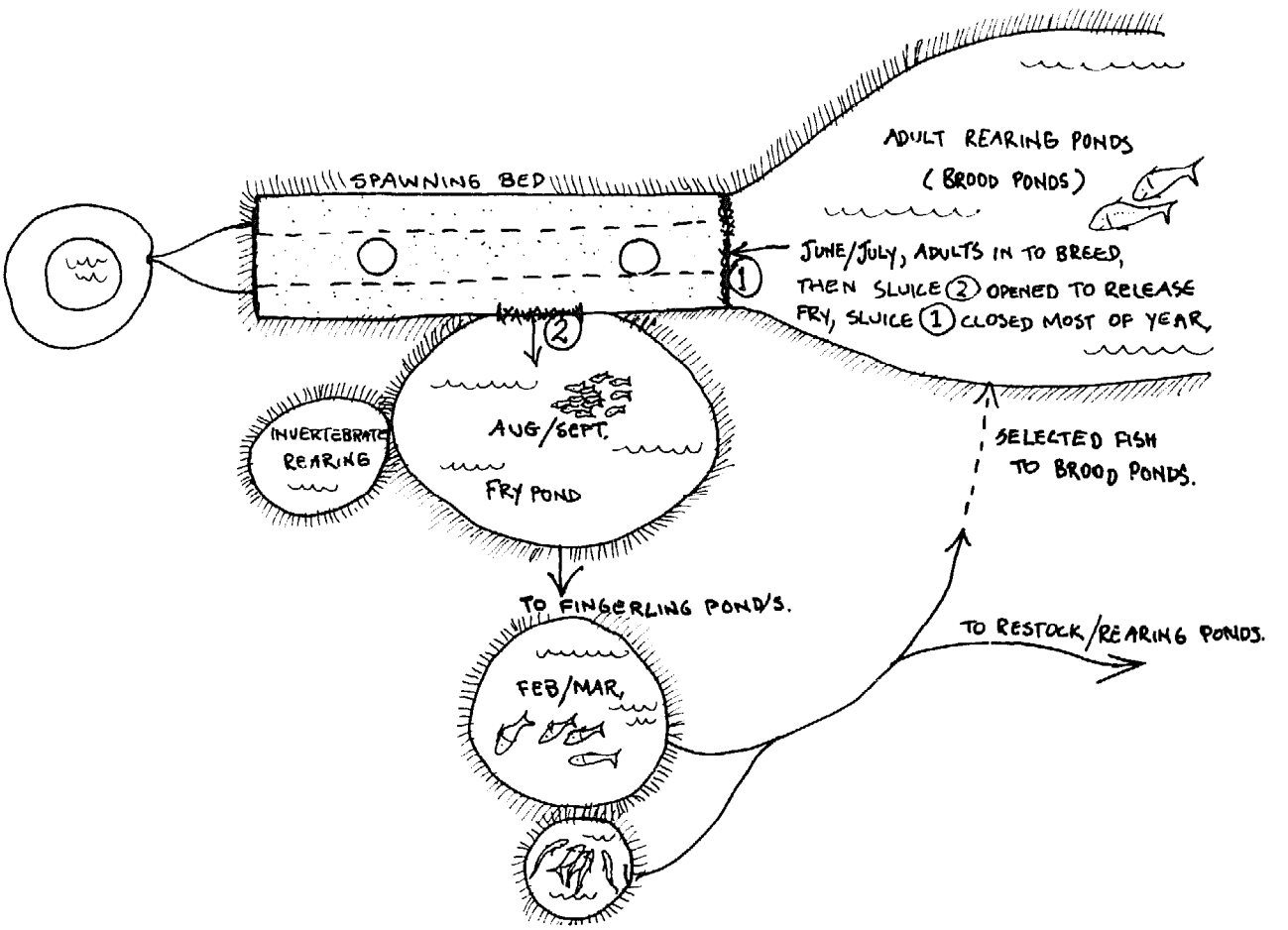


FIG. 7.20: TYRE ISLAND (FRESH OR UNDERWATER REEF).

PLATE 7.4: VIEW DOWN MAIN DAM WALL OF PLATE 7.3. VALVE IS OPEN TO FLOOD IRRIGATION CHANNEL.



GRAVEL SPAWNING FOR SPECIES LIKE TROUT, IN STILL PONDS. FIG. 7.21



SCHEMATIC POND SYSTEM (TROUT) FIG. 7.22

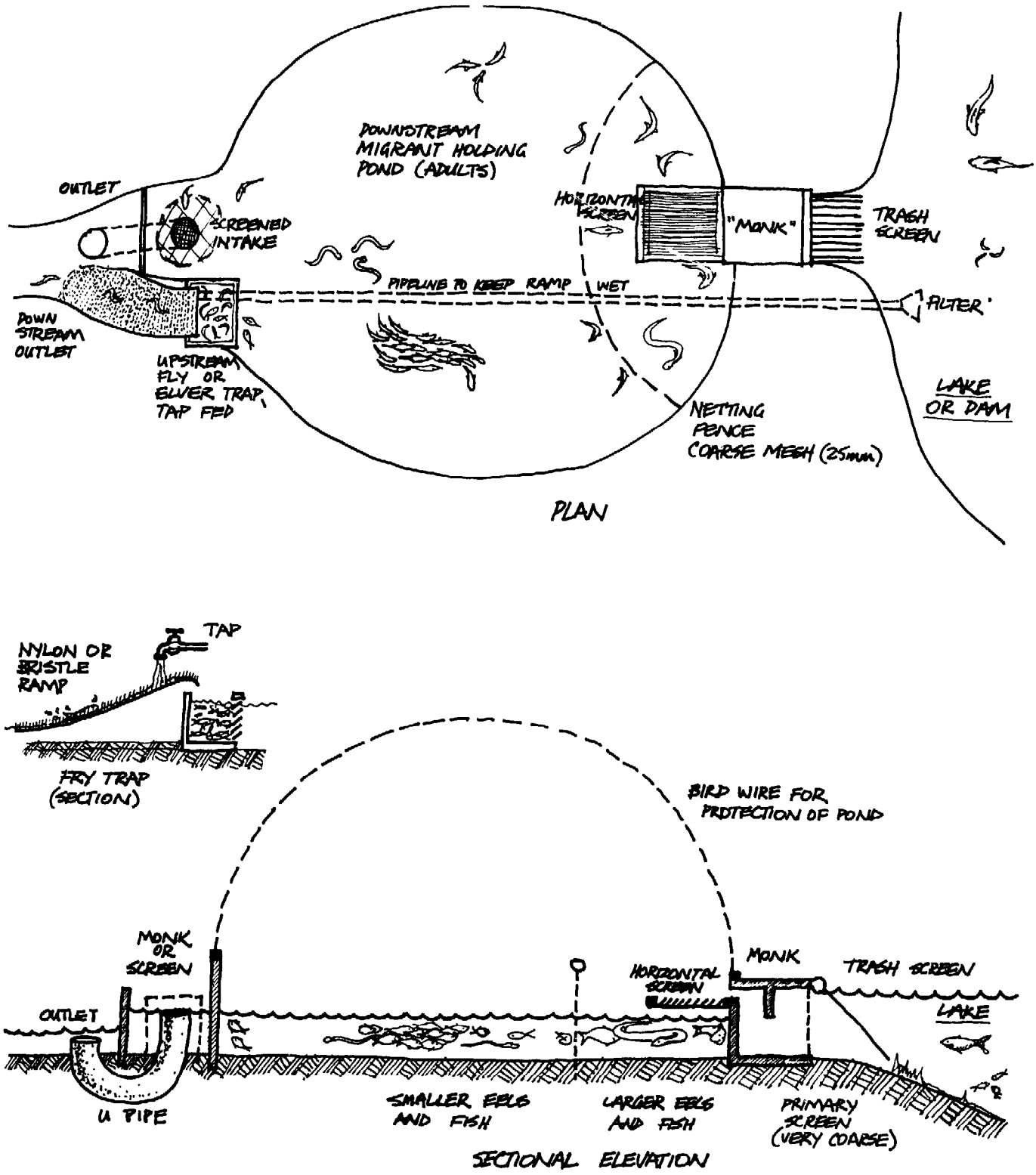


FIG. 7.23: COMPLEX OUTLET DEALING WITH CAPTURE OF UPSTREAM FRY, ELVERS, DOWNSTREAM ADULTS (EEL POND PLUS SOME FISH). POND HOLDS ADULTS MOVING TO SEA.

All authors concur that less disease and greater total productivity are a feature of polyculture, and that monoculture in ponds, as on land is less stable and more energy-consuming. Thus, the dilettante emphasis on trout or salmon fisheries for sport only at this stage (Tasmania) has resulted in several energy-expensive and foreseeable problems:

- large lakes and rivers overstocked and underfished, with dwarfed or stunted fish and low turnover. Some need to be opened to commercial fishery;
- no real assistance to still-water pond culture on farms—no real data or species available;
- heavy over-regulation of fish farms and waters, so that we employ many more 'policemen' than biologists (the public is the enemy, as usual);
- no real assistance for habitat improvement for any but trout species;
- restrictions on the import of useful, non-sporting species;
- no commercial inland fishing except for eel (which is a trout predator!)
- introduction of trout into national parks and isolated waters (would pigs be allowed to run in botanic gardens, or hunters licensed to stick pigs in public parks?). Thus, no real protection of native fish habitat;
- no research into useful plant species, new pond fish species, or management of estuaries for their fish populations;
- the concept of a minimum size limit as a dogma—hence poor fish stocks.

And so on. This (as in cotton monoculture) produces all the evils of biological and social disruption, the definition of "pests" as species which eat trout, and the creation of a favoured group of sportsmen, while millions of gallons of water and tons of protein are denied to everyman, and millions of fish die of old age.

It is now seriously proposed, by people like Prof. Bloom, of the University of Tasmania, that certain shallow estuaries should be dammed for protein production, just above tide level in order to prevent pollution by marine waters. Due to metal processing and wood pulp industries, Tasmania has offshore levels of zinc, cadmium, mercury and like dangerous heavy metals as high as anywhere in the world, but then the coasts of all industrial nations are either overfished or polluted, thus negating a natural source of fish protein by wastage of the resource.

Despite all these setbacks, amateur fishermen take, in total, about as much scale fish as commercial fishing boats; it remains for state governments to reform their ways, and for the rest of us to dig ponds in case they are too late in so doing.

SALICORNIA FLATS 7·5

The intergrade estuary or inlet to land is often over *Salicornia* flats, weakly inundated by tides twice daily. Swan, where present, graze these systems at high tide, and domestic geese also appreciate the forage of succulents and saltgrasses. As few, if any, fish occupy these salt flats, mosquitoes find multitudinous breeding grounds there, and it is more productive to vary the system by pond and bank designs, as per Fig. 7.24, than to try to manage the unmodified system.

Data from Colin Sumner (Tas. Fisheries, in conversation) suggests that ponds of about 1.8 m deep, with very gradual bank slopes (1 : 3 or so), allowing a foot of tide as flushing, and provided with browsers such as periwinkles or *Salinator* shellfish, shrimp, and mullet to keep algae to tolerable levels, would also provide excellent oyster culture conditions, with broodstock at mid-bank and spat caught on broken shell in trays, for transfer to nearby estuaries (at 40% air time exposure, 60% submerged). Geese on range, and ti-tree or coastal shrubs on embankments make a more varied ecology, with manurial input to ponds.

Mullet species are also viable pond species if some food is available or cultured in ponds; crab, octopus, seaweeds, and shrimp are other probable cultures.

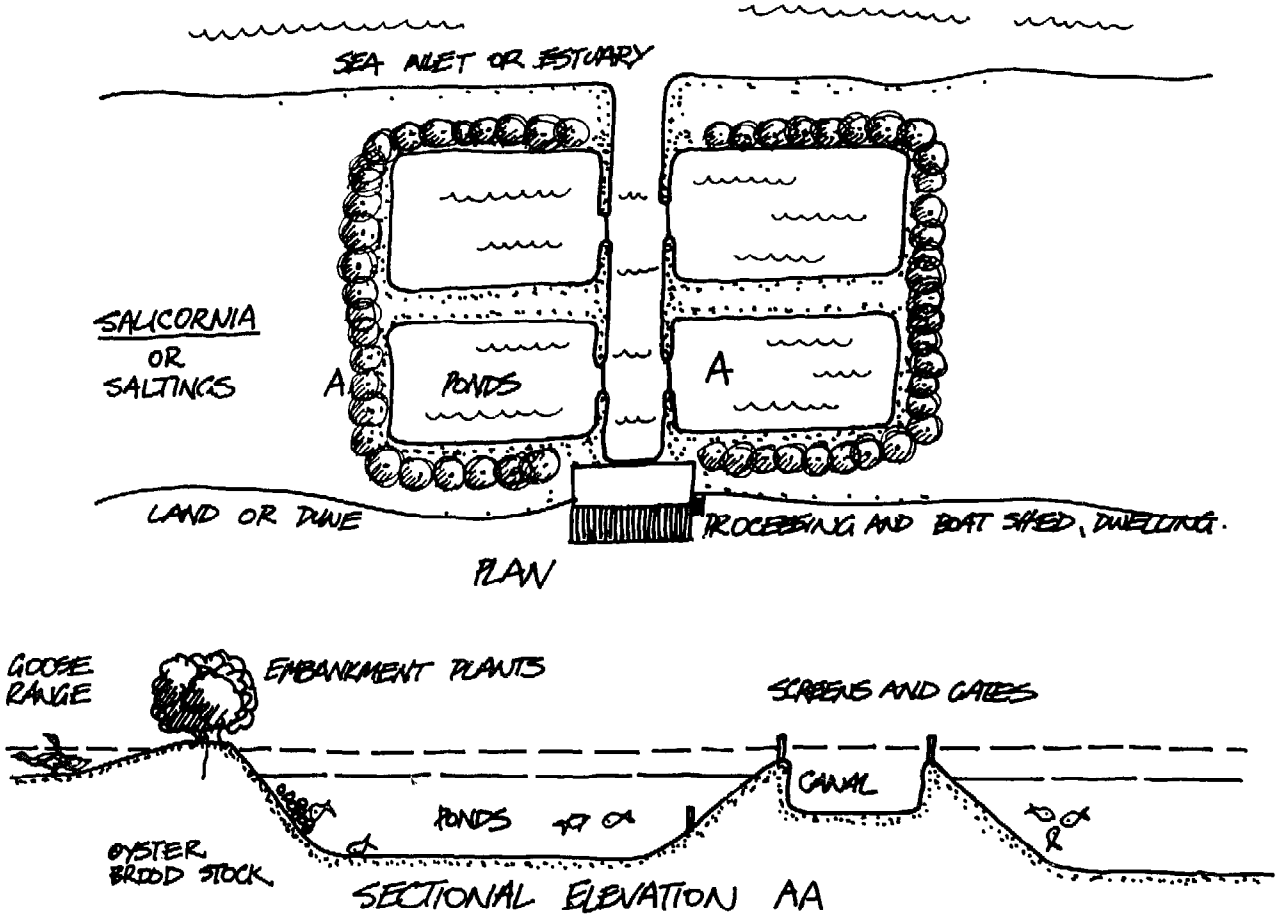


FIG. 7.24: PLAN AND SECTION OF TIDAL POOLS.

7·6 MARICULTURE

"Water-based ecosystems are as complex as those on land. The ecosystem approach must be applied there just as in terrestrial food production."

Sciences Council of Canada, 1979.

As in any analysis of calorific versus economic policy, it is clear that offshore and intensive process fisheries, such as are still being developed by Japan, Russia and the west for open sea species and fishmeal are doomed in energy terms. Sedentary, shore-based, estuarine, inland, and intertidal or tidewater fisheries, now much depleted and neglected, will not only yield higher than deepsea fisheries, but can reduce or eliminate the main costs of transport, packaging, and storage of products.

There are very few shellfish and inshore species, including such forms as oyster, crayfish, eel, octopus, seagrasses, algae, shrimp, sand bivalves, and scale fish that are not susceptible to rearing or management in pond or barrage cultures, raft culture, and fenced or impounded tidal areas. Yet most research, bureaucratic facilitation, capital input and human effort goes into the offshore multinational, non-sustainable long-range fisheries; fisheries which employ very few men, allow little local industry, and waste enormous tonnages of fish and by-products.

Redirection of resources to inland, estuarine, and inshore systems must become a policy priority if this cheap protein source is to be preserved. The implications for control of polluting industry are obvious. In practical terms, sea reef structures developed from tyres, broken or faulty

earthenware, and local stone provide a substrate and shelter for larger forms of fish (eels, octopus, crayfish). Stone "fields", or lines of stone (long developed in western Ireland) set out in shallow water "catch" algae as seaweed ponds, as does woven fencing. Manurial input stimulates seagrass growth, hence estuarine waterfowl production, and a variable ecology that has the highest productivity. 7.6

The essential structures that will reform the many millions of hectares of invariable mud-flats and intertidal sands available are:

- reef walls of tyres, pipes, stone;
- drift fences to catch seagrass and direct fish;
- rafts for rope suspension of mollusc spat and algae, ring-rafts to rear fish in tideways (as in Ireland, where salmon are reared to adulthood in seaways);
- flow-governed tide pools to permit correct exposure for growing oysters;
- fry traps that provide stock for inshore and *Salicornia* pools (Fig. 7.24);
- accessory paddle-powered electric or mechanical systems at points of restricted tide-flow;
- evaporative pans for salt, chemical, and brine-shrimp production (the latter as fry food);
- islands for marine wildfowl refuges and phosphate collection;
- deeps for fish refuges, provided with cover nets or refuges from cormorants;
- manured sea-grass fields, wave-protected by low bunds, yielding seagrass and browsing fish;
- sub-surface (permeable) walls to retard tide flow in scoured estuaries; and
- trials of substrate materials to catch new fry or algal forms.

The same advantages of slope, sun reflection from still-ponds, and a mixed ecology of wildfowl, geese, fish, molluscs and algae apply to seawater or brackish ponds as they do to the freshwater systems discussed elsewhere. The greatest advantage is a tide range of 1-9 m, such as is found over most coasts, and therefore enables 'free' flushing and governable draining of ponds; the filling of higher-level impoundments for later release to lower ponds; and a flow of open sea species, fry, and algal forms as food.

Swan, geese, and some duck species prefer saltwater locations or *Salicornia* and *Zostera* fields, while mullet species, eels and bream are all easily managed fish species with different food requirements, hence giving a management potential as mixed-species stocks. Mussels and oysters attach to stone or still-pond *Zostera,* hold sand banks with byssal 'roots' and provide bream and human food. Tagari has applied for a tidewater and Salicornia leasehold to test out some of these strategies, and will develop a research series of structures and impoundments should funds be available.

It is in the variation or complication of naturally invariant areas, long ago reduced to fairly barren plains by sea action, that the greatest opportunity to increase inshore fishery yields lie. More importantly, the guano from seafowl, easily caught as liquid run-off from solid rafts or stony islands, provides the essential local phosphate and nitrogenous fertilizer for adjacent land crops. Even large artificial platforms have proved commercially viable off southwest Africa, where pelican and cormorant use these "islands" for roosting, and deposit tons of guano for fertilizer. In more humid climates, rain takes the guano into solution, so that storage tanks or covered solar evaporative pans need to be provided.

Sea-grass mulch and guano close the sea-land cycle of nutrients, and makes the growing of crops near seashores and waterways very profitable. And yet, seafowl (especially seagull rookeries near towns) are seldom, if ever, structured to be used as guano reserves, and in the waste society their riches are lost to the sea, while guano is mined elsewhere.

In both hemispheres, burrowing and surface-nesting seabirds can also be 'managed' for eggs and meat production, fine down, and manurial output. The muttonbird (*Puffinus*) industry of Tasmania yields millions of birds annually; but under good management, the rookeries are fast increasing. By-products of down make the best insulation for "doonas", beds, and even rooms. Like any fowl, muttonbirds can be cultivated, and rookeries established in new areas. The adults will survive well in captivity, and their progeny return to new rookeries. Thus, any seaside property can have a rookery of these birds if located in the general range of the selected species. Similarly, seal rookeries can be developed (as on the Pribiloff Islands) to safely yield skins, guano and protein foods.

7.6 It is known to all net (seine) fishermen that shallows off such rookeries are very productive of seagrasses, hence fish such as pike, garfish, and whiting. The guano of seals and seabirds, culled from squid, rough fish and invertebrate krill, is the basis of the high manurial turnover in the inshore sea pastures. Once removed, the seals often fail to return, or are senselessly shot by gill-net fishermen as "pests", thus lowering the total yield of the sea. In the tropics, dugong and manatee, turtle and crocodile have similar niches and management potential.

1 Tidal Stone Traps

Where tides fall 1.2 m or more on rocky coasts, as in N.W. Tasmania, tide traps are made from well-packed stone, so that rocky clefts or tidal flats are enclosed by a 90 cm wall. At high tide, the small school fish (garfish, squid, mullet, perch) enter over the wall, stay to feed on algae in the enclosed area, or are baited by crushed mussels, and are trapped as the tide falls. A refuge pool (or better, a roofed and slotted tank free from bird predators) holds the catch at low water. Late night tides give the best catch, and we frequently visited these traps when young. An old gate or door in the wall allows the whole system to remain open when not in use. Such traps provide small fish for stocking manured ponds, and are themselves a substrate for oyster and mussel.

STILLWATER FUNNEL TRAPS

When tide-fall is too slight, or in lakes and lagoons, a lead fence plus a series of funnels guide fish (eels, trout, perch) to enclosures. (As net systems, these are called fyke nets.) On dams, the end enclosure can be under the house verandah, and fish kept there are always available. The system is widely used in marine shallows both in the U.K. (Scotland) and Malaysia, and in deeper water for tuna schools (Italy). Such traps can be made of brush, stone, wire, or fabric netting. The final catching pens are roofed or completely enclosed to foil predators and jumping fish.

2 Seagrasses - Zostera, Heterozostera and Posidonia

Various seagrasses or swan weeds grow in Australian estuaries. Some, on most open coasts, have short broad leaves, some wiry and strong, some like hay, and some like peat, mixed with a fluffy algae. All are a public resource, excellent insulators, and very resistant to burning. Intelligent use of such resources offers a safe way (safe, that is, from lung cancer caused by mineral fibres) to insulate houses. In Victoria, at least, the material is on sale for roof and ceiling insulation, but it is available to any vigorous householder. In Adelaide, and in many areas *Zostera* is a 'nuisance' on beaches and near boat ramps. Again, careful usage converts a nuisance to a very conservative resource, long-lasting and safe.

The tougher material is almost immune to rot, and even under slabs would insulate from the ground if fumed with creosote, soaked in a weak preservative solution, or encased in thin plastic covering. This insulates buildings from ground cold, and prevents heat escape to the earth, making concrete slabs a large heat-storage system.

The spring growth is used by water fowl as grazing, and there is a heavy summer seed production, useable as forage seeds or for flour.

FREE-RANGE POULTRY DESIGN 8

While it is possible to document (by way of listing plant species) and to plan free-range designs for any animal species, I have chosen here to treat poultry as livestock. Here poultry is used in the widest sense, to include waterfowl, landfowl, pigeons, and even emu.

Perceptive readers, scanning the plant list (8.4) will notice that it is also a bee forage system, and would evolve into a cattle forage situation over time. Many of these species also withstand sea winds, salted soils, and frosts, so that coastal and desert (inland) situations are suited.

It is true (in Australia at least) that coasts and deserts support, in their natural state, a great variety of seed-eating and berry-eating birds, from quail to emu, as well as heavy populations of part-insectivorous birds (such as guinea fowl, pheasant, and ducks) especially where local flooding provides the essential water.

For poultry, plant systems quickly evolve. In the case of pheasant and quail, a simple reduction or elimination of herbivorous browsers (rabbits, cattle) permits plants to seed, and provides seed forage in a single summer. Provision of crop-stones as gravel, and shell-grit for egg calcium (where native snails are few) enables poultry to deal with the harder seed-coats of many plant species.

In the plant list, species suited to windbreak, hedgerow, understorey and herb layer are indicated, so that normal design planning applies in structuring the poultry forage species system.

While there is a new emphasis on free range systems, they are seldom (if ever) specified, and I know of none designed to function as such. Turner[33] comes closest with his cattle pastures, but omits the structural design allowed by correct placement of hedgerow, grain or oat crop, and shelter.

By planting and observing a variety of forage species, we greatly reduce (perhaps even obviate) the need for stored, husked grains, and should therefore be ahead in terms of energy 'economics'. In Fig. 8.1 I have indicated the spatial layout of such a forage system centred on a homestead, and Figs. 8.2 and 8.3 elaborate the theme. More observations of bird/plant associations are needed for more elaborate designs, but the species listed give a balanced basis for beginning, with "fail-safe" strawyards (deep-mulched and gate enclosures to produce emergency food from grains and pulses). There are the following integrated systems to consider on a broad scale (2000 m^2 or so—½ acre—and upward):

- the hardy free-range system of Zone II, plus the normal orchard species—stored foods gathered from here;
- strawyards for seasonal forage, gleaning, and production of stored seeds;
- throwover pens for more tender greens and highly-selected browse species such as chard; and
- storage bins or sheds to store hard foods for the spring "hungry gap" when seeds and berries are few.

There are certainly possibilities for evolving very broad-scale poultry forage systems, using pigeons, quail or pheasant, in field shelters to harvest the crop. The spacing of field shelters will be dictated by such factors as keeping pure-bred flocks separated, the normal ranging habits of the birds, and the scale of the operation (the time available to harvest eggs or meat products).

We know little about the optimum balance of plant and animal species, but, in any case, this may depend more on the snail or insect population of the area than on prior planning. Normal hygiene, or prevention of infection between species must also be considered, and species selected for egg or carcase yield.

Aquatic or part-aquatic (edge) systems need further work, as do trials of the free forage system.

In the wider context of permaculture planning, a poulty forage system can be integrated with:

- fire control by scratching, raking, grazing;
- glasshouse heating using body heat of birds;
- honey production from the flowers of forage crop species;
- stored food for larger stock species (e.g. goats);
- home orchard production;

- seed production for store or sale;
- manurial waste disposal systems, hence annual gardening or composting;
- pest control on the range, which can encapsulate the home garden as a pest barrier (for control of grasshoppers, and snails as an example);
- general product diversification (roadside sales, etc.); and
- evolution to a large-animal (cattle, deer) forage system.

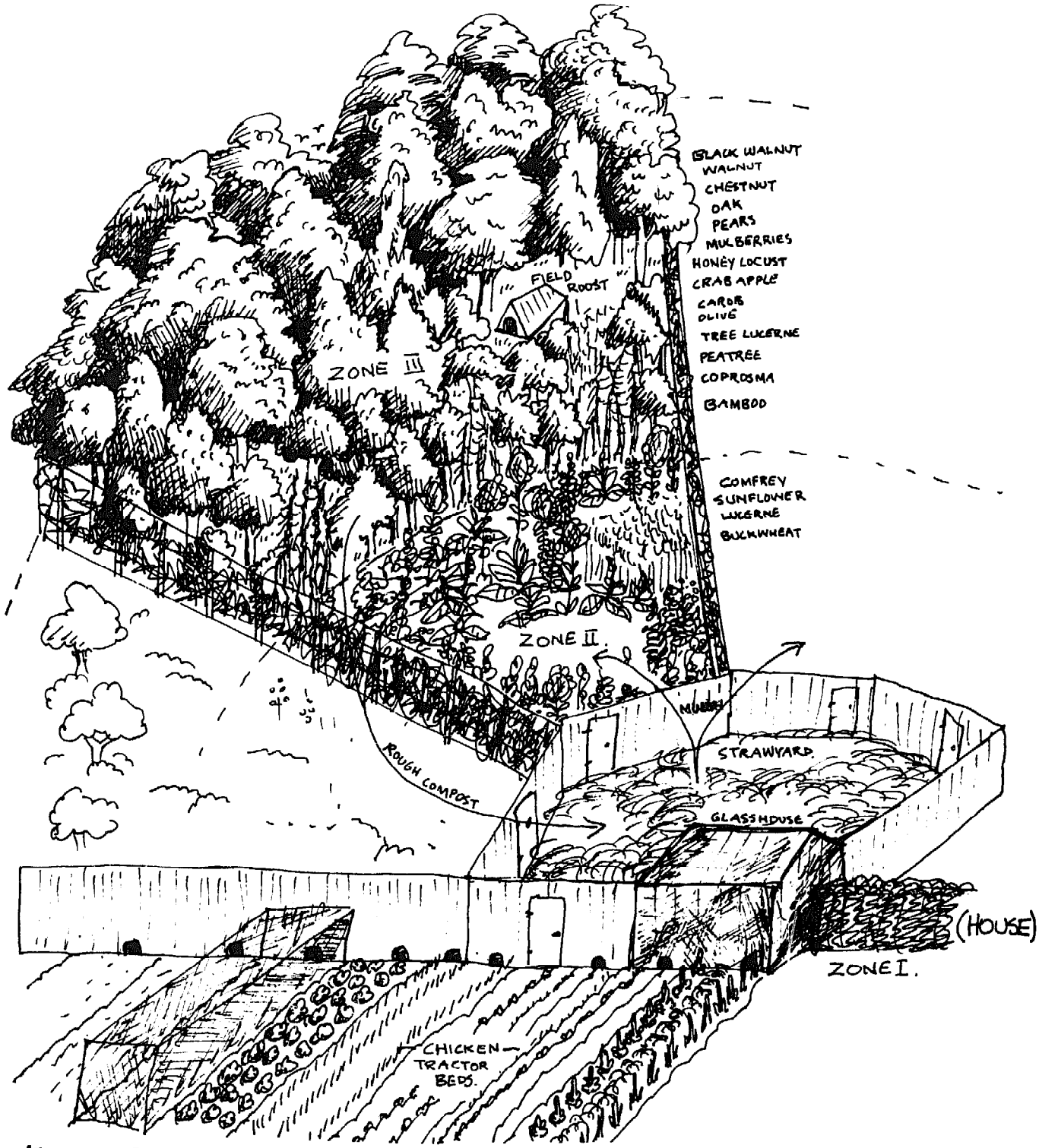
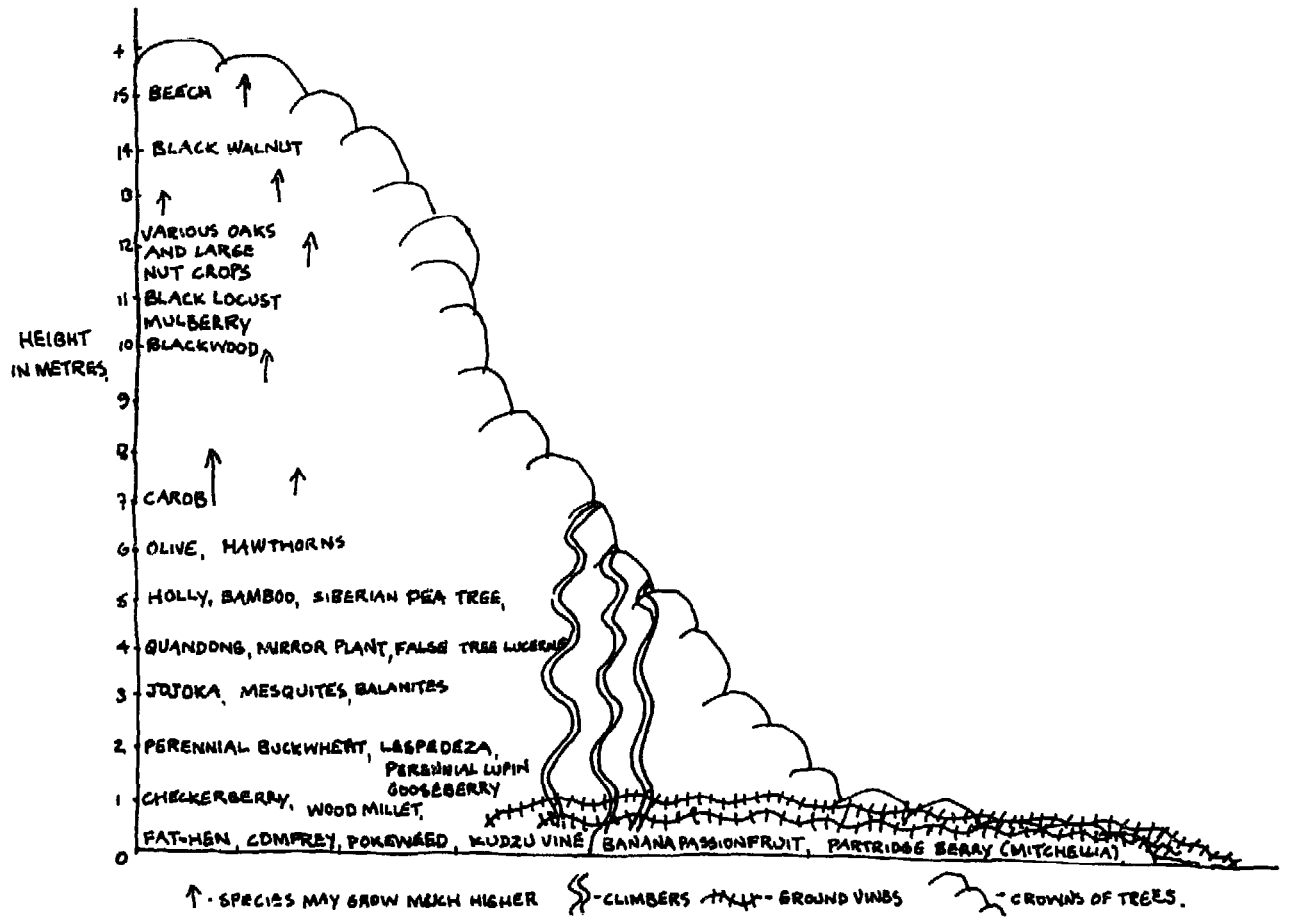
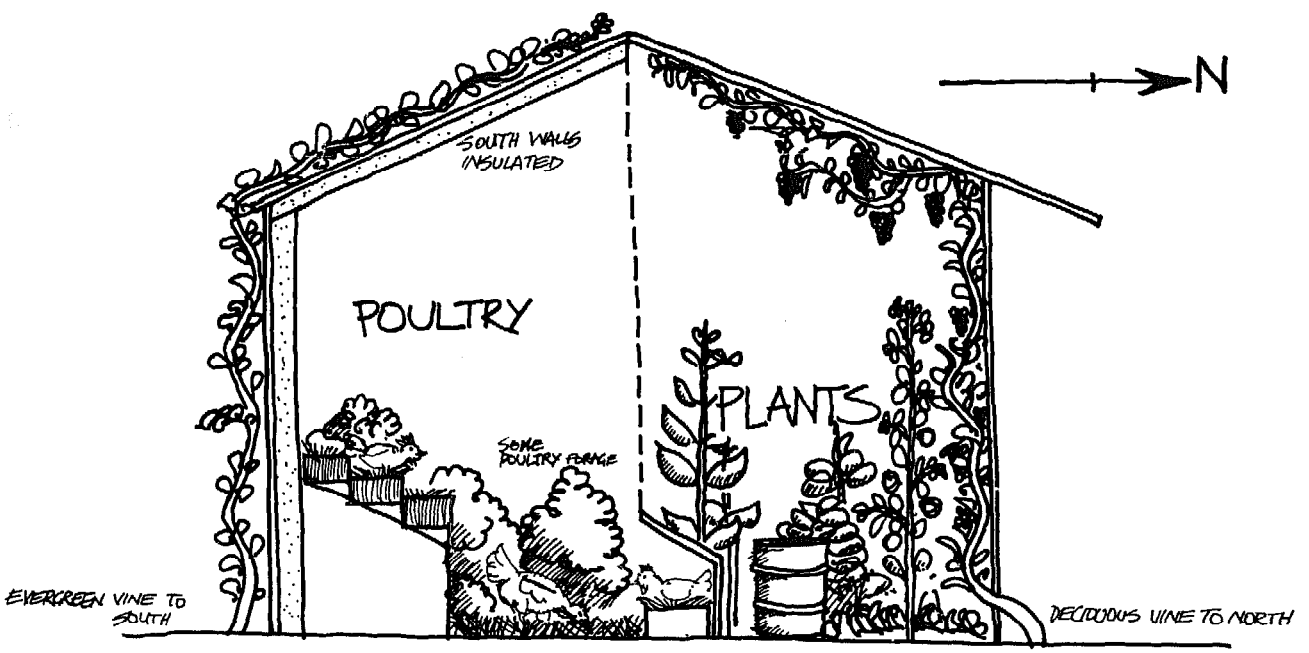


FIG. 8.1: POULTRY FORAGE SYSTEMS.



HEIGHT STRUCTURE OF A DEVELOPED POULTRY FOREST. FIG. 8.2.



CHICKEN HEATED GLASSHOUSE. FIG. 8.3.

8·1 ESTABLISHMENT

As for orchards, and in line with soil conditioning and mulch processes already outlined elsewhere. The area must be controlled for browsing herbivores, sown to herbal leys, and nitrogenous or leguminous plants established as manure crop for the slower-evolving trees, shrubs, herbs and root crops.

Initial costs are in fencing, initial mulching of strawyards, in buildings, water supply and stock provision (both plant and animal species). As in most permaculture or complex systems, species such as fungi and insects soon begin to complicate the system and may provide resources beyond those planned.

Because of the high manurial and mechanical turnover in strawyards or pens, quite rough bracken, cornstalk, hedge clipping and straw residues are quickly shredded and decay to mulch, as they do in sheds. Weed control can also be achieved by regulating the time and density of stocking rates, and the species permitted to range. Small species such as ducks, hens and guinea-fowl can be stocked from the beginning, and geese added after the first year or so.

8·2 FORAGE STORAGE

Stored food draws from two main sources:

- hard seed pods and seed heads from strawyards; and
- gathered or raked windfalls from walnut, oak, carob, and like trees.

Forage storage needs racks, dry shelves, bins, wires for corn cobs (or cribs), drying floors or pits for acorns and chestnuts, and overhead hooks or racks for sunflower heads. Pest-proofing from rats and sparrows is essential, and a small hammer mill a great asset.

8·3 REGULATION OF YIELD

Yield needs to be regulated in two ways:

- for steady forage yield (to reduce storage needs); and
- for regular carcase or egg yield.

Insofar as seasonal forage drop is concerned, there are few problems. As a suggested pattern: hard seed (*Acacia, Robinia, Caranga*) falls mainly from early summer, but has some residue all year. Berries follow in late summer and autumn, and persist to late winter. Large seeds (walnuts, acorns) persist from autumn to spring, or all year if gathered and dried, and greens and annuals carry over in spring and early summer.

Regular egg yield may need poultry variety selection (Dorkings for winter, with some ducks, heavy breeds for spring, Leghorns for summer laying). Pigeon and quail, more closely managed, yield for most of the year, if age classes are kept mixed. Professional breeders who wish to avoid mechanical brooders, use Wyandottes and/or silky bantams for brooding the eggs of other species.

When we reach more sophisticated levels, it will be possible to express the 'value' of certain trees and plants in terms of P.F.D. or "poultry forage days". That is, the value of a mature tree lucerne may be about 2.5 kilos of seed, which would keep a hen for 30 days or so on free range. Already, Smith[31] has stated that a black walnut at maturity will keep 8 hens all year, so that a single tree like this is of 365 × 8 = 2,920 P.F.D. value. If we work out these equivalents, plants of high value, even if they are slow to grow, can be preferentially planted. Fig. 4.2 was, in fact, worked out on a "cattle-day" basis by the Victorian Agricultural Dept., and this is also how Turner[33] assesses his herbal leys and pastures. A friend in Perth (W.A.) reports that his 17 year old carob yields a 3-6 bean daily supplement for 3 goats all year (gathering only some of the beans) and that this is sufficient sugars and "concentrates" for them to deal with on rough range, so that a carob has at least 1,000 G.F.D. (goat forage days) concentrate value.

As far as blackbirds, starlings and woodpigeon are concerned, they too can become (*via* traps or mist nets) part of the protein crop of a forage system.

As Neil Douglas (in conversation) points out, poultry on range can be very useful weeding mechanisms, and if we chose plant species useful to us but not much damaged by poultry, we could have a work-free garden! One instance is *Oxalis* spp., eagerly eaten by hens, but a pest to small-fruit growers. Neither small-fruit nor asparagus are much affected by hens, although geese are (of course) heavy grazers of gooseberries and smallfruit. Poultry will, in time, kill out persistent but selected herbs (although slow re-invasion may take place). Hence their value in orchards other than the manurial benefits they give.

Predator control: Birds preying on poultry are largely foiled by a tree-forage system, where domestic stock such as ducks, pigeons, guinea-fowl and hens can escape into shrubberies or roost in trees. Ground predators such as the fox are a real problem, but ways of controlling these are suggested in Figs. 8.4 and 8.5. Again, hens at roost may be used as "baits" for ground predators, and their sheds fitted with a ground-level live-trap to capture foxes for use or deportation. Large flocks of pigeon, housed in secure, raised lofts are largely imune from predation, and may be the most useful poultry for 'wild' areas.

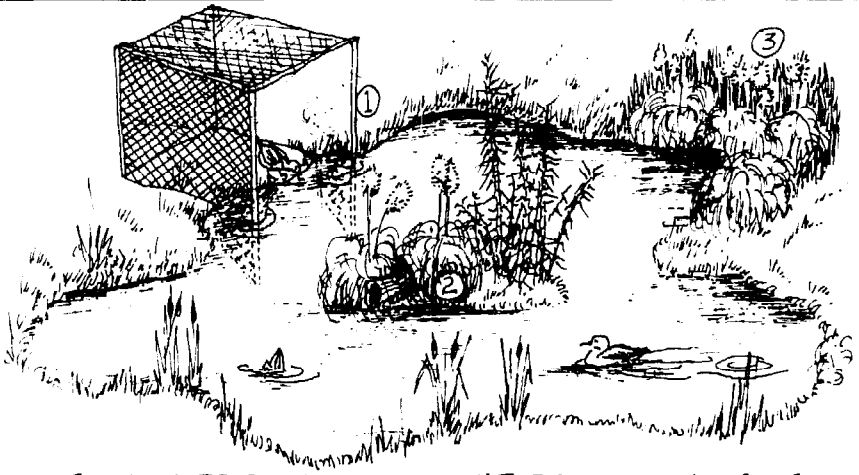


FIG 8.4: FOX PREDATION PREVENTION — WATERFOWL. 1 COVERED CAGE, FRONT IN WATER. 2 ISLAND WITH PAMPAS, BAMBOO, HOLLOW LOGS. 3 SHALLOW, MARSHY AREA WITH PAMPAS FRINGE.

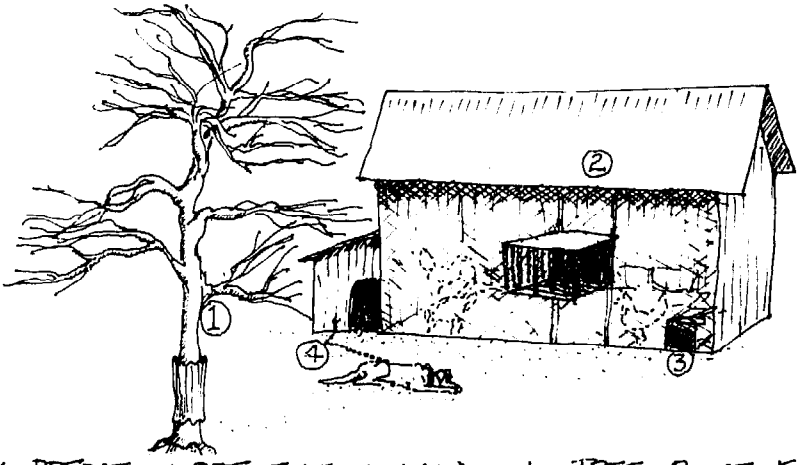


FIG. 8.5: FOX PREDATION PREVENTION LAND. 1 TREE ROOST FOR GUINEA FOWL, PEAHEN. 2 NETTED HOUSE WITH FOOT WIPER (STEEL) PROJECTING HORIZONTALLY AND HUNG WITH SHORT CHAINS. 3 FOX TRAP ENTRY TO SHED. 4 SMALL DOG KENNELLED ON RANGE.

8·4 DOCUMENTATION

(An annotated species list of plants known to be useful as poultry forage). This list (while unique in intention) is certainly not exhaustive, and any significant additions would be welcomed.

1 Species with Seeds and Pods in Summer

SHRUBS AND TREES

TREE LUCERNE (*Chaemocytisus proliferus*)	Early to mid-summer seed drop. Foliage also edible. Hardy. (The false tree lucernes (*Cytisus pallidus, C. pullilans* are also of use.)
LESPEDIZA (*L. bicolor, L. cytobotrya. L. sericea. L. striata*)	As above.
ATRIPLEX (salt-bushes) (*A. halimus,* many other species).	Wind, salt, and pest resistant shrubs.
PEA TREES (*Caragana arborescens, C. siberica*).	Used mainly as poultry fodder, but seed can be eaten.
CAROB (*Ceratonia siliqua*)	Seeds and pods stored for milling.
HONEY LOCUST (*Gleditsia triacanthos*)	As above.
BLACK LOCUST (*Robinia pseudoacacia*)	Seed. Leaves may poison stock.
MESQUITES (*Prosopis* and *Strombocarpa*).	As for carob, and as resistant to salt and drought.
ACACIAS:	It is in this genua that we seek, and find many hard-seeded species eaten by man or his domestic stock, and by wild birds. In some both pods and seed are edible. Restricted examples are:
Acacia giraffae (Africa)	Ground-up pods fed to livestock.
A. albida (Africa).	Excellent also as a nurse tree in crops.

A. aneura, A. kempeana, A. boloserica. A. cowleana, A. victoriae, A. binervata, A. longifolia. A. peuce, A. oswaldia. All from Australia, all useful as human food in emergencies, and all drought, salt and frost hardy.

Albizia	Appear to have characteristics like those of acacia.

Trees and Shrubs Yielding Nuts or Acorns 2 for Storage (Autumn - Spring)

BLACK WALNUT (*Juglans nigra*)	Store for 12 months.
PERSIAN WALNUT (*J. regia*)	As above.
CHESTNUT (*Castanea saliva*)	Store for 6 months only, unless chilled, or dried in the sun.
OAKS (*Quercus spp.*)	Almost all acorns are edible for poultry. Acorns are easy to collect and store in damp earths or swamps, or dried, or fresh for short periods of the year. Recommended as poultry food in the U.K. in wartime.
Balanites Spp.	Kernels of fruits stored for stock food.
BEECH (*Fagus* spp.)	Yield oil-rich nuts irregularly.

Berries and Fruits Yielding Flesh 3 or Seed (late Summer - mid Winter)

Lycium ferocissimum, L. chinensis.	Thorny hedges with berries and seeds late summer to late winter. Salt and wind tolerant. Eagerly sought by poultry.
Coprosma spp. (*C. lucida, C. australis, C. parviflora, C. repens, C. Kirkii, C. robusta*).	A useful and hardy set of N.Z. plants for coasts, swamps, understorey, shelter plants. (See Metcalf, L. J. *The Cultivation of New Zealand Trees and Shrubs,* Reed, Wellington, 1972, for culture.) Most are dioecious and need about 5% male plants. Almost all grow from cuttings or as quickset hedges. *The N.Z. Whole Earth Catalogue* (1975) states that poultry survive all year round on 3 or so of these species. Stock like the foliage, which is also of good manurial value. Trees prune well to hedges.
MULBERRIES (*Morus alba, M. nigra*).	Important poultry food of high protein value.
ELDERBERRIES (*Sambucus spp.*).	As for mulberry.
EMU BERRY (*Owenia reticulata, O. acidula*).	A noted food for that species, and for pigeons.
PALMS	of a great many species yield nuts and fruit for storage in sub-tropical and tropical areas.
KARREBOOM (*Rhus lancea*)	A hardy poultry berry bush.
Canthium latifoliam ((Aust.).	A desert shrub with edible berries, as is the Berrigan (*Eremophila longifolia*).
Crataegus spp.	and service berries provide a range of fodders.
CHANAL, CHILE (*Gourlila decorticans*)	is also used as fodder.

8.4 4 Vines for Fences and Trellis

Dolichos spp.	Annual and perennial beans, probably well-suited to pigeons. Species range from temperate to tropical, evergreen perennial to annual.
Passiflora spp.	As for Dolichos. The fruit of the banana and black passionfruit are both eagerly eaten by poultry. Banana passionfruit is frost-resistant and will "trellis" on most trees (including eucalypt) if planted at the drip-line.
KUDZU VINE (*Thunbergia*)	Is a free-seeding rambler recommended for poultry feed.
Chayote (Choko)	Also of use waste piles or low trellis.
GABIZURA (*Actinostemma lobatum*)	A scrambler with oily seeds.

5 Roots

Nut-grass (*Eleocharis*) and sour-grass (*Oxalis spp.*) yield shallow tubers utilized by birds, although they are pest species in other areas. Oca is a special culture of *Oxalis*. Poultry eat the *Oxalis*, leaves and stems.

Jerusalem Artichoke (*Helianthus*) can be pulled as needed, especially in lean periods, and flourishes under oak forest or in poor soil.

6 Greens and Seeds as Herb Layer

On extensive free range, the herbal layer should not be neglected, and clovers, medics, lucerne, chicory, asparagus, plantain, fennel, and the herbs recommended by Turner[33] may be sown, with mixed grasses. Ducks and geese also appreciated the seed-heads of rye grasses and clovers. Pokeweed (*Phytolacca Americana*) is eaten by birds, especially pigeons.

Wood millet (*Milium effusum*) lupin species, perennial buckwheat (*Fagpyrum cyanosum*), partridge berry (*Mitchella repens*) below pine trees, or in acid conditions; checkerberry (*Gaultheria procumbeus*) Soulkir (*Agriophyllum gobicum*) can be used as whole plant greens, or for seeds, as can *Celtis australis* and *C. occidentalis*. Wild rye (*Elymus condensatus*) tolerates moderate salinity and wild rice (*Zizania aquatica*) yields heavily in ponds for duck forage, as do *Lotus* spp. and strapweed (*Triglochin*), together with the algal pond weeds.

7 Species for Broadcast Sowing in Strawyards

SUNFLOWER	*Helianthus* spp. (Heads stored in autumn)
MILLETS	*Panicum* spp.
CORN	*Zea*
BUCKWHEAT	*Fagopyrum*

And the usual grains of wheat of wheat, rye, barley, oats, teff, etc.

Chenopodium	(many species) is also loved by poultry. Most broadcast grain crop is easily stored, as are the pulses (below) for pigeon and poultry feed.

CHICK PEA	Tolerant of a fairly wide range of soils and climates.	8.4
LENTILS	As above.	

Lab-Lab or small Dolichos beans as ground cover.

FIELD PEAS	a great variety exists.
Centrosemia	useful in tropics.

Not known to the writer as poultry food, but a probable success would be the Amaranthus grains of South America, of which some 1000 varieties are cultivated. *Eragrostis* and *Portulaca* seeds are also used, in Australia, as human food. Linseed can be judiciously used, as can (in happier times) the seed of marijuana or hemp (Cannabis), once an important bird food.

Herbs, 'Weeds' and 'Throwover' Crop 8

SHEPHERDS PURSE *Capsella bursa-pastoris*):	Turner[33] recommends this herb as a poultry forage and states that "it has a stimulating effect on egg production". As it may be a nuisance in areas where it is not wanted, poultry are a valuable control.
CLEAVERS (*Galium aparine*)	another useful seed plant for poultry (Turner, *op. cit.*) which is a nuisance elsewhere. "They love the seed and readily consume the whole plant when its iron and iodine content are very valuable, especially to yarded or deep-litter birds. It is well worthwhile to gather Cleavers solely for the purpose of feeding it to intensively-kept poultry." For free-range poultry Cleavers may need to be protected by brush or netted fence enclosures. Again, poultry are useful as controls on this species.
PLANTAIN (*Plantago major, P. lanceolata*):	recommended by Lawrence Hill and others as a crop which can readily absorb chicken manure waste and produce lots of green fodder. Eagerly sought by ducks in local trials.
CHARD	the first choice of all greens, but free poultry access cannot be permitted. Successional sowings in throwover area ensures year-round leaves for green forage.

Layout 9

It only remains for the homesteader to gather these warps of plants and wefts of animals into a logical weave. Some layouts are already figures and suggested, others may evolve from observation, or be modified by local conditions. Salt marsh may suggest more geese, wetlands more ducks, and deserts more quail or pigeon in the species mix.

The plants should be arranged to hedge and shield the buildings, permit observation, and reduce losses from exposure to sun, wind, rain and predators.

9 ON PERMACULTURE AND COMMUNITY

Of Ludo Chardenon, a traditional herbalist in Provence, Lawrence Durrell has this to say:

> "I saw him as belonging to that obstinate tribe of men, the creative yea-saying ones, who are obstinately holding the pass . . . until the rest of us come to our senses, and decide what we want to live for, and with, and how. Yes, it is up to us."
>
> (*The Plant Magic Man ; Yes*! 1975)

Spreading the gospel of quiet, responsible gardening is indeed the "one-straw revolution"[3] that yea-saying men seek.

All of those mentioned care more for health, land, and humanity than for themselves, and all are busy people in many fields; all are 'lateral thinkers' or multidisciplinary in the best sense. The organic farming movement is part of the new revolution in self-sufficiency in country and town, as the Down to Earth Movement started by Jim Cairns and Juni Morosi is the new synthesis of alternatives in lifestyles. May they all prosper.

The global village community is in the throes of its formative years, and should produce over the next decade, the most remarkable revolution in thought, values, and technology that has yet been evolved. This contribution is intended to speed not the plough but the philosophy of a new and diverse approach to land and living, and make the plough obsolete.

For myself, I see no other solution (political, economic) to the problems of man than the formation of small responsible communities involved in permaculture and appropriate technology, for both individual and competitive enterprise and 'free' energy have failed us. Society is in a mess; obesity in the west is balanced by famine in the third world. Petrol is running out, and yet freeways are still being built. Against such universal insanity the only response is to gather together a few friends and commence to build the alternative, on a philosophy of individual responsibility for community survival.

Listening to Jacques Cousteau (A.B.C., Aug. 29th, 1977) I was inspired by his call for scientists to use plain words and to turn their energies to life processes useful to the common man. Sir MacFarlane Burnett in Australia makes a similar plea, as yet little heeded by the education industry in a country where even government-employed foresters and agriculturalists spend most of their energies in research for large properties or firms, not for the individual or small group, and where industry and government offer expensive and often dangerous centralized energy systems.

I believe that the days of centralized power are numbered, and that a re-tribalization of society is an inevitable, if sometimes painful process. The applied theories of politics, economics and industry have made a sick society; it is time for new approaches. We live in the post-industrial world, and have an immense amount of sophisticated information and technology which enables us to exchange information while living in a village situation. Permaculture is a basic technique for such an evolution, and like all biological, wholistic systems, is within the reach of everyman.

Permaculture both conserves and generates the fuel energies of transport systems, and would enable any community to exist comfortably on very restricted land areas. Supplemented with the appropriate and available technologies of methane and alcohol fuels, dry distillation processes, and wind, wave, water or solar energies, it would provide the basis of a sustainable and regionalized society. Combined with community co-operation, permaculture promises freedom from many of the ills that plague us, and accepts all the organic wastes of the community it serves.

Thus, a permaculture system integrated with human settlement provides an inexhaustible energy system, fueled by the sun and developed by the community.

In moving towards such a safe society, all we have to fear is fear, for in the end the only security lies within ourselves, the only safety in having friends, good neighbours, and a meaningful society of man.

A society which spends as much on the arms race in one hour as it spends on famine relief in a year must inevitably perish from war and famine. Why should we any longer permit high energy houses, cars, freeways and armaments to be built when we are in danger of dying of inaction? Unwilling as some of us are to act we must find ways to do so for our own survival. Not all of us are, can, or need to be, farmers and gardeners. However everyone has skills and strengths to offer and may form or join ecology parties or local action groups to change the politics of our local and state governments, to demand the use of public lands on behalf of landless people, and to join internationally to divert resources from waste and destruction to conservation and construction.

Permaculture One, was, often enough, regarded as a political book. On reflection, perhaps it was, and if so it was a quantum leap away from existing political treatises, in that it suggests that man does not need a waste society or centralised power, only regional self-sufficiency and worldwide communication.

The lack of humour and foresight, humanity and common sense, that characterises *all* present politico-economic systems is appalling. The whole world is disenfranchised, with satellites spying on us from above, and multiple Idi Amins at ground level; refugees afloat and en route, and famine and obesity taking equal tolls on health.

We are told that we have an energy crisis. That is a lie while we continue to build freeways and bombers. We are told that we cannot accept refugees. That is a lie while we destroy surplus grain. We are told we need sewerage, 10-square (minimum) houses, and a job. That is a lie too, as this book may help to show. What we do need is a working group of good-humoured people pledged to world citizenship, self-reliance, and an ethic of social and individual responsibility. Every dwelling needs a tank, dry toilet, a small glasshouse, an insulated space and a garden. Nobody needs the flush toilet and a monopoly on political and economic power ("the runaway bus with no driver at the wheel").

There are no utopias in the offing, and no blueprints for one, but man could create a saner, happier, less alienated and more humane world. Human society is complex and I do not pretend to have all the answers, but it seems to me that we will have taken several steps in that direction if we can pledge ourselves to:

- world citizenship, membership of spaceship earth;
- global communication and education;
- aid to others to establish self-reliance, not create dependence;
- self-reliance in ourselves and our group (village, tribe, community);
- care of the earth;
- absolutely no waste products, hence no "unemployed";
- adoption of the most sophisticated environmental principles we can know;
- a moratorium on freeways, arms, centralised power, and export of any energy sources not used in accordance with these principles;
- gradual removal of all tariffs, passports, visas and impediments to travel (true world citizenship);
- open media devoted to spreading these principles (especially appropriate electronic media, which save forests).

For Intentional Communities:

- all groups/neighbourhoods limited in size from 300-3000 (no more or less less), and at least 5 locations for each group, one of these to be an "overseas" centre (groups never to have a fixed boundary);
- community ownership of land and public resources (life leases on homes and gardens, to be sure). The cruel myth of "ownership" of resources and people is where we have lost touch with reality, evolved paternalism and lost the right to define our own employment and worth.
- Regional groups to choose specialized 'trade' manufactures suited to local resources, skills, inclinations and markets; and

- a programme to make every house and town self-sufficient with teams from each stabilized area advancing into disaster areas and the third world (which lies within as well as without affluent nations);
- global federations of specialized groups in travel and trade, exchange of skills, with mobile groups based on transport systems.

All we need to do to achieve this is to start. Even 1000 people have enormous personal resources, land, housing, income and ability. With these shared, all would have more than enough.

"Enough" is a warm place, good nutrition (hence, health), plenty of information, many friends, a meaningful task or two and reliance on the group, hence absolute security. Who needs insurance, spy satellites, or any of those expensive waste products of insecurity? Multinationals, like national pride, are a result of greed and the need to hold what you have. Perhaps the greatest truth is that we can only own the resources we give to others. As Titmuss (*The Gift Relationship,* George Allen and Unwin, 1970) so clearly enunciated, a world totally governed by private market principles ultimately deprives man of the "freedom to give", the *right* to behave altruistically. We are fast approaching this point, and the consequences for human society will be nothing short of disastrous. Think that one over and join the "world self-reliance volunteers". There are plenty of fights and adventures to hand: the fight against cold, hunger, poverty, ignorance, overpopulation and greed; adventures in travel, humanity, applied ecology, and sophisticated design—which would be a far better life than most people are living now, and would mean a life for our children.

FURTHER RESOURCES 10

It would make this book very bulky and expensive had we included a species list, as in Permaculture One. Several practical designs are also omitted, as these are specific to site, and again add to costs. However, we are preparing a great deal of additional material and carrying out our own research, as outlined below.

DESIGN CONSULTANCY

At Tagari we subsist on our own gardening, and by publishing and consulting in Permaculture design. A design team is active (Ted Lamont, Bill Mollison, Andrew Jeeves, Simon Fell, Peter Moore), and others are being trained in field work. Members of the consultancy will travel for lectures, seminars, and planning sessions on quote (fares pre-paid). Specialties are planning for unemployed and disadvantaged groups. We also like to work for other communities.

Designs have been completed over a great variety of situations and climates, in factory interiors and for public authorities and instrumentalities. Associates are specialists in educational architecture, reactive housing, agricultural science, keyline planning, horticulture and aquaculture; any of these can be called in for specific works. Fees are currently those of landscape architects, or normal architectural fees, but we claim we are worth it.

For small local designs, a minimum fee of $300.00 covers fares and the design report, ground plans and species documentation: for large properties, architecture, and public works we will quote on design or work to a normal hourly rate. Travel beyond 6-800 kms must be arranged by the client, and can often be offset by local lecture fees or workshops in the area. Where possible we do cost-price designs for Aboriginal or disadvantaged groups.

All designs hold strictly to a low-energy, safe, and reactive philosophy; for those who cannot afford $300.00 we also have a set of "Standard Designs" (see listing below) and we will include others on specific request, providing these are on clearly-defined and limited subjects. Most of these designs include ground plans or sketches.

STANDARD DESIGNS

These are supplied as looseleaf sheets, and are updated at regular intervals. A full list can be had for S.A.E. (large) and 40c stamps. Samples are:

LANDSCAPE (SERIES L)

L1. Rock dome planting (for granite and exposed rock areas).
L2. Tidal flat ponds.
L3. Flatland dam (below grade) and house site.

PESTS AND PROBLEMS (SERIES P)

P1. Mosquito control techniques.
P2. Blackberry control.
P3. Fox predation prevention.
P4. Planting in the presence of rabbits.

ANNUAL GARDEN DESIGN (SERIES A)

A1. Tomato/Asparagus polyculture.
A2. Culinary herb spiral.
A3. Home production of potatoes.

MARKETING AND MANAGEMENT (SERIES M)

M1. Farm-Link: involving town with country.
M2. Wayside marketing.
M3. Self-pick sales.

TECHNIQUES (SERIES T)

T1. Pruning in permaculture.
T2. Sewage disposal—domestic.
T3. Sewage disposal—community.
T4. Planting on broadscale.
T5. Uses for tyres.
T6. Fuel production from plants.

STRUCTURES (SERIES S)

S1. Trellis structures and planting, sun traps.
S2. Collecting water from rock dome seepage.
S3. Shade house—documented.
S4. Attached glasshouse—documented (give latitude).

SPECIFIC SPECIES LISTS (SERIES D)

D1. Complete list of poultry forage species.
D2. Hedgerow species—barrier hedges.
D3. Cattle forage species.
D4. Pig forage species.
D5. Sea coast species for salt, wind resistance.

URBAN STRATEGIES (SERIES U)

U1. Contract cropping in Neighbourhoods.
U2. Dispersed tree crop with contract sales.
U3. Dispersed livestock with contract sales.
U4. Types of Public Allotments.

(The emphasis of this group is on meaningful employment.)

(Please request any special design or documentation you may need. All designs are copyrighted. Prices range from $4-15.00 to date.)

PERMACULTURE QUARTERLY AND ASSOCIATION

The remarkable Terry White, (of 37 Goldsmith St., Maryborough) edits our Quarterly Journal for the bargain price of $8.00 p.a. at present (which only just covers printing and distribution costs). In this worthy journal we list requests, supplies, exchange news and views, and spread our net to cover permaculture, appropriate technology, and community. Any overseas group who wishes to start a local newsletter may do so by application. Gifts are always welcome—we are usually in financial straits as an association!

Local suppliers may obtain one free listing of useful species if they submit a list. Members are encouraged to collect and sell or exchange selected local seed. Groups wanting help may call for it here, and most general letters on permaculture should be routed to the Quarterly.

THE PERMACULTURE INSTITUTE

Tagari have purchased 78 acres of coastal swamp and dryland in Stanley, Tasmania, and (with local gardens) have designs and plans in operation, as from January, 1979. The main land area will be devoted to demonstrating techniques of planting and design, and still-pond culture will be a feature. We are assembling species of sub-tropical to cool temperate range (there are no frosts), and appreciate seed or divisions of rare species, water plants of use.

The institute will research and become a resource for species for southern Australia—a sort of permaculture arboretum. We aim to become partly self-supporting by charging for admission, 'schools' and visitors, and by the sale of seeds and plants. The commercial crops on site will be nuts, some fruits, water plants, and aquatic birds/poultry. Planting is progressing well, but we need earthworks and more species. Formal organisation will be notified in the Quarterly.

PERMACULTURE SPECIES INDEX

We are preparing a looseleaf species index of useful plants and animals. The first 1,000 species or so should be available by January 1980. Please enquire then. Species are described according to standard sheets, and will cover all climates and niches. Several useful short lists will be extracted as the work proceeds. Special attention will be given to design potential, placement, use, and processing.

TAGARI

Membership of Tagari is open to all easygoing workers, preferably with some capital to house themselves or to help house themselves at this stage. Enquiry by letter. A mutual trial period of membership (minimum 3 months) is necessary. Accommodation is short.

Tagari is a full commitment community, where a trust will hold all property in common, a partnership will run the 'business' and all income and resources are shared. Members live in family houses. The association itself is not registered, and makes its own on-going decisions. Warehouse space and land is ample for present needs. Housing is short until we acquire more capital or are able to build.

Except for the Quarterly, enquiries on all aspects should be directed to

Tagari,
P.O. Box 96,
Stanley,
Tasmania 7331. (Phone: (004) 581105, 10-4 p.m.)

11 MAIN REFERENCES

1 Mollison, B., and Holmgren, D.
Permaculture One. A perennial agriculture for human settlements.
Transworld (Corgi, Bantam) 1978. Melb.
(This first book in this series, dealing with the rationale for a new look at perennial agriculture, and the need for design.)

2 Yeomans, P. A.
Water for every Farm
Murray, Sydney, undated.
(P. A. and Ken Yeomans have greatly assisted the writer, and others, by clearly explaining their methods of landscape analysis and soil treatment.)

3 Fukuoka, M.
The One-Straw Revolution
Rodale Press, Emmaus, Pa. 1978.
(Perhaps the most significant book on permanent agriculture. Should be translated into all languages and given away by all governments.)

4 Phillips, S. H., and Young, H. M. Jr.
No-Tillage Farming.
Reiman Associates, Wisconsin, 1973.
(An early, technological work on the rise of "no-dig", but sprayed, broad-acre agriculture.)

5 King, F. H.
Farmers of Forty Centuries
Rodale Press, Emmaus. Pa.
(The classic on eastern agricultural methods, emphasis on permanent systems of growing annuals.)

6 Papanek, V.
Design for the Real World
Paladin Books, 1974.
(A seminal book for the meta-industrial technologist.)

7 Stout, Ruth, and Clemence, R.
The Ruth Stout No-Work Garden Book
Rodale Press, Emmaus. Pa.

8 White, Deborah, *et alia*
Seeds for Change. Creatively confronting the energy crisis.
Patchwork Press, Melb. 1978.
(The essential Australian energy crisis book—politicians please note.)

9 Williams, C.
Craftsmen of Necessity.
Vintage Books, N.Y. 1974.
(A pleasure to read, shows deep understanding of passive systems of buildings and farming.)

10 Day Lewis, C. (*Trans.*)
The Ecologues, Georgics and Aeneid of Virgil
Oxford Univ. Press. 1977.
(Ancient, if fragmentary, plant and animal husbandry.)

11 Lovelock, Y.
Vegetables, An Unnatural History
(Curious, literary, and practical information on a great variety of edible plants.)

12 Logsden, G.
Small-scale Grain Growing.
Rodale Press, 1977
(Like all of Gene Logsden's books, this one is practical and useful. With refs. 3 and 13, the grain grower can proceed.)

13 F.A.O. (Rome) 1961.
Agricultural and Horticultural Seeds
(A valuable compendium for the crop gardener.)

14 Watt, K.
Principles of Environmental Science
(A handy guide to the rules of good environmental management and analysis.)

15 Hickling, G. F.
Fish Culture
Faber and Faber, London, 1962.
(Standard text on the title subject.)

16 Chakroff, Marilyn,
Freshwater Fish Pond Culture and Management
V.I.T.A. Manual, Series 36 E, 1976.
Available from: Fish pond culture, 3706 Rhode Island, Mt. Rainier, MD 20822, USA.

17 Poulsen, G.
Man and Tree in Tropical Africa
IDRC 101e, 1978.
Available from: IDRC, Box 8500, Ottawa, Canada, KIG 3H9.
(Excellent essays on tropical agriculture.)

18 Andersen, E.
Landscape Papers
Turtle Island Foundation, Berkeley, 1976.

19 Odum, Howard T.
Environment, Power and Society
John Wiley, N.Y., 1971.

20 Mollison, B.
Arid Land Permaculture
Tagari Pub. 1978.
(Now forming Section 5.1 of this book.)

21 Howard, Sir A.,
An Agricultural Testament
Oxford Univ. Press. 1943.

22 Van der Muelen, G. F.,
The Ecological Methods for Permanent Land Use in the Tropics
Ranonkelstaat 119, The Hague, Netherlands (Undated).
(Complements Poulsen's papers on tropical ecology.)

23 Evenari, M., *et alia*
Agronomy Journal, 60, 62, 63. (A series of articles on run-off farming in arid areas.)

24 Hall, N. *et alia.*
The Use of Trees and Shrubs in the Dry Country of Australia
Aust. Govt. Pubs. (AGPS), Canberra, 1972.

25 Brokenshaw, P.
The Pitjantjatjara and their crafts
Aboriginal Arts Board, 1975.

26 Cleland, J. B.
in: *Aboriginal Man in South and Central Australia.*
Govt. Printer, Adelaide, 1966
(Native species)

27 Latz, P. K.
in: *The Nutrition of Aborigines in Relation to the Ecosystem of Central Australia.*
CSIRO, 1978.

27a Maggs, D. H., As above.

27b Frith, H. J., As above.

28 *Permaculture Quarterly,* Terry White (Ed.)
37, Goldsmith St., Maryborough, Vic.

29 Gollan, Anne,
The Tradition of Australian Cookery
A.N.U. Press, Canberra, 1978

30 *Pitjantjatjara Homelands Health Service,*
P.M.B. 65, Alice Springs, N.T. 5750
(Newsletters and News-sheets).

31 Smith, R.
Tree Crops: a permanent agriculture
Devine-Adair, Old Greenwich, 1977.

32 Kern, Ken.
The Owner-Built Homestead.
Owner Built Publications, Calif., 1974.

33 Turner, N.
Fertility Pastures,
Barggler Rateaver, 1974.

34 Fisher and Yanda,
The Food and Heat Producing Solar Greenhouse,
John Muir Pubs, New Mexico, 1976.

35 McCullagh, James C.,
The Solar Greenhouse Book,
Rodale Press, Emmaus, Pa., 1978.